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EVALUATION OF EXTERNAL SEALING METHOD TO REDUCE STORM FLOW EFFECTS IN SEWERAGE SYSTEMS

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Sonoma County Sanitation Department
California

1968

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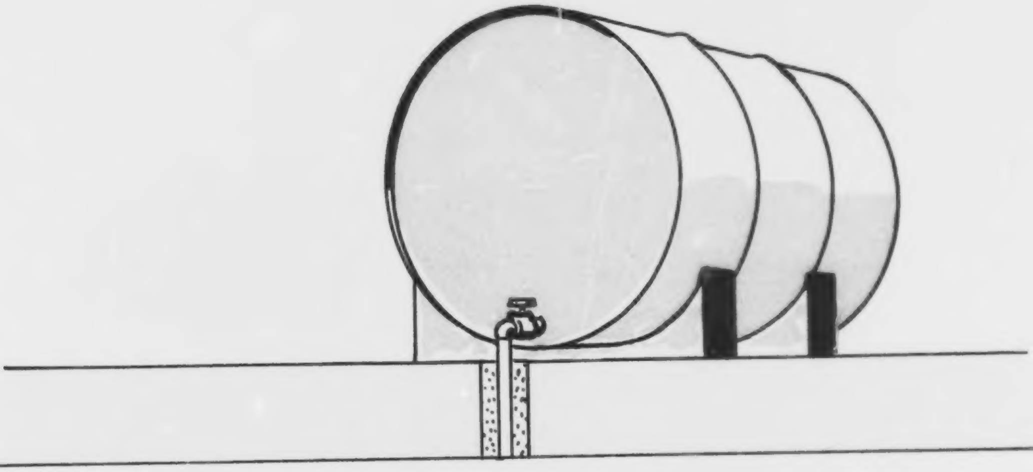


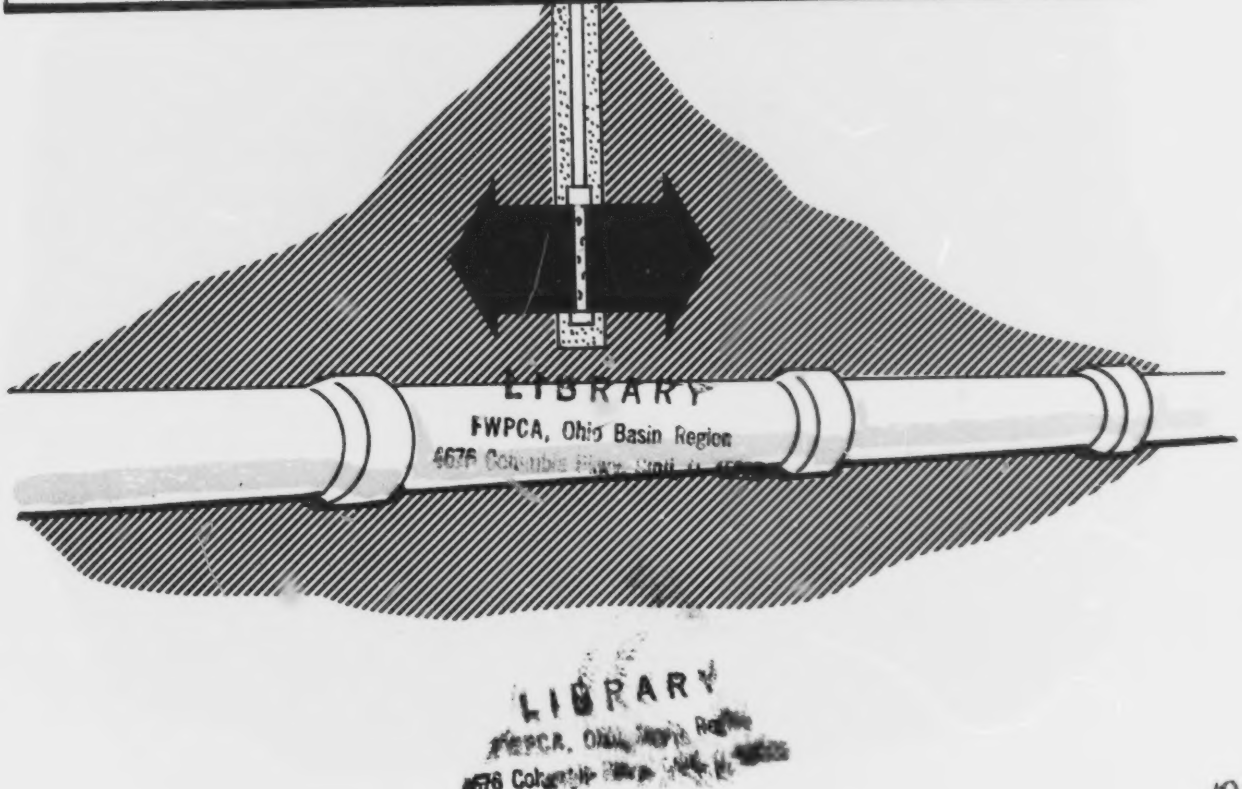
Evaluation of External Sealing Method to Reduce Storm Flow Effects in Sewerage Systems

FINAL PROGRESS REPORT

F. W. P. C. A. Demonstration Grant WPD 111-01-66

COUNTY OF SONOMA, SANITATION DEPARTMENT

PROJECT DIRECTOR: Donald B. Head, Sanitation Engineer



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PROJECT DIRECTOR: DONALD B. HEAD, SANITATION ENGINEER

This project was supported in part by Federal Water Pollution Control Administration Grant WPD 111-01-66 from the United States Department of the Interior.

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INTRODUCTION

Infiltration problems are common to many communities throughout the United States. Designing collection systems which can adequately collect and transport sanitary sewage depends not only on the quantity of sanitary sewage to be handled but also upon the quantity of storm and ground water infiltration which must be anticipated. Ground water and storm water contributions to sewage flow can be limited by:

1. Eliminating roof, yard, and foundation drainage.
2. Minimizing flow through manhole covers.
3. Reducing infiltration.

While the greatest control on the extent of infiltration is competent inspection of collection system construction - and backing up the inspection with comprehensive construction standards - many sanitation districts and departments have "inherited" systems which transport heavy flow during and after rainfall.

When this hydraulic overloading hits the treatment plant (and frequently before it reaches the plant) bypassing occurs, either by design or by accident.

Since the overflow is a mixture of raw sewage and storm water, untreated sewage is being delivered out of the collection system to streams or other water courses. Particularly with advancing urbanization, the need for reduction of infiltration is emphasized.

By comparing per-capita flows, it can be demonstrated that extensive exfiltration occurs in leaking sewers during summer months when the water table is lowered. This exfiltration, in turn, contributes to ground water pollution.

While this report is confined to the sealing of sanitary sewage collection systems, the problem of inhibiting excess flows in storm drains and in combined sewers can be similarly regarded. The concept of sealing storm drains may seem superfluous at first glance, but the overflow of storm drains (which are acting as leaching lines) only adds to the stormwater load which finds its way into sanitary or combined sewers. In addition, the flushing action of excessive storm water flow in storm drains causes heavy loading of organic material as the settled material in storm drains is moved out.

The importance of the economic aspects in the control of infiltration can also be considered. Obviously, excessive flows increase capital costs of pumping and treatment facilities as well as adding the cost of oversized sewers. However, the financial decision as to the economic wisdom of pouring large amounts of money into sealing and repair programs which do not provide positive results vs. replacing bad sewer lines must frequently be made. In the case of the Sonoma Valley County Sanitation District it has been found that the use of an external sealing method in conjunction with replacement of house service laterals has resulted in considerable reduction in infiltration.

This reduction has justified the expenditure of District funds for the sealing and repairing program. It has been estimated that the cost of this program will result in the expenditure of approximately 25% of the total replacement cost of the entire leaking sewer system.

It is the intent of this study and report to describe the use of an external application of asphaltic sealants in several different localities. By actually sealing leaking lines in areas of differing soil characteristics and in systems which employ differing pipe and jointing methods, it has been possible to include a sufficient variety of conditions to approximate conditions common to many communities in the United States.

This project was supported in part by Water Pollution Control Demonstration Grant No. WPD-111-01-66 from the Federal Water Pollution Control

Administration, Research and Training Grants. That the Federal Water Pollution Control Administration is vitally interested in the investigation of new methods for control and prevention of water pollution is clearly defined by FWPCA Commissioner James M. Quigley who recently said: "There are few more challenging, more difficult problems that we face in this country than the problem of bringing to this land the clean water that is absolutely necessary for its continued prosperity and growth".

Project Objectives

(1) To collate and analyze the available backlog of data pertinent to line sealing. Included in the collation is the organization and evaluation of colored stereo slides, field notes, rainfall records, sewage flow records, pertinent reports, personal diary notes, meter records, correspondence files, and related material in the files and records of the Sanitation Department of the County of Sonoma.

(2) To further investigate this method of line sealing under a variety of field conditions to determine the feasibility of applying the method in various types of soils and under varied conditions of moisture.

SCOPE OF STUDY

The extent to which collation, and analysis was conducted can be determined by review of the available collation section of the report. Colored stereo slides were viewed, identified, filed and listed. Field notes were transcribed from Department field books. Rainfall records, and sewage flow records were re-plotted on graphs in order to show visual comparisons between rainfall and sewage flows. The sewage flow charts and meteorological charts which were used to develop the graphs are not included in the collation because of space limitations. Reports which have a direct bearing on the development and early application of the line sealing process are included verbatim. Field and office personnel who kept personal diaries were requested to submit same for inclusion. In a few cases, minor editing was necessary in order to present a coherent picture. Personal and technical correspondence was referred to in gaining background information, however these files are not included.

Original field application of the line sealing method was confined to an area in which a granular type of soil is rocky or semi-rocky formation is characteristic. Investigations conducted for this project included the following study areas:

(1) Forestville County Sanitation District
The line selected for test is 159 lin. feet of 6-inch vitrified clay pipe with mortar joints, installed in an area of silty sand.

(2) Occidental County Sanitation District
The test line is 330 lin. feet of 6-inch concrete pipe with mortar joints, installed in an area of clay and shale.

(3) Bodega Bay

The test line is approximately 40 lin. feet of 8-inch vitrified clay pipe with mortar joints, constructed and installed with poor joints intentionally built-in for test purposes. Located in a tidal flat, this line reflects the effects of salt water immersion on the sealing process during high tides.

(4) Sonoma Valley County Sanitation District

The test line is 546 lin. feet of 6-inch vitrified clay pipe with hot-poured joints, installed in sandy clay (adobe).

The scope of study, as related to the field application, includes most variables which could be anticipated in the existing construction of older sewers in Sonoma County.

Evaluation of the results of this method of line sealing will be indicated generally in the chapter entitled: Summary and Conclusions. Specific results are discussed in the chapter entitled: Study Areas.

ACKNOWLEDGEMENTS

This project was supported in part by a Water Pollution Control Demonstration Grant No. WPD 111-01-66 from the Federal Water Pollution Control Administration of the Department of the Interior.

Assistance for this project has come from a number of sources, and the Project Director gratefully acknowledges this assistance.

Included among those assisting are:

Board of Directors, Sonoma Valley County Sanitation District;

Engineering-Science, Inc., of Arcadia and Oakland, California;

Mr. Laurence W. Dickey, Observer, Department of Commerce Weather Bureau, Sonoma, California:

Mr. Bruce Parmelee, San Rafael Equipment Company

Maintenance crews of Sonoma Valley and South Park County Sanitation Districts: and the Engineers and Technicians who are members of the Sonoma County Sanitation Engineer's staff.

HISTORICAL BACKGROUND

The "Evaluation of an External Sealing Method to Reduce Storm Flow Effects in Sewerage Systems" had its beginning when the Sonoma Valley County Sanitation District was faced with a major problem of storm water infiltration early in the existence of the District sewage collection system.

A 24-inch outfall line had been completed to Highway 12 and stubbed-off at Schellville, California, prior to placing the Sonoma Valley Treatment Plant in operation in 1954. During the winter of 1953-54 a portion of Highway 12 near Schellville had to be barricaded because the stubbed-off 24-inch line was - according to later estimates - delivering 6 million gallons per day of infiltrated water to this highway crossing. The flooding was reported to the State Highway Maintenance Superintendent by the Schellville Maintenance Station Foreman on January 18, 1954.

This action occurred before the Sanitation District came under the jurisdiction of the County Sanitation Engineer's Office.

The magnitude of the infiltration problem was intensified because of the fact that no house service laterals had been installed at this time nor had the City of Sonoma been connected to the system as of the time of the flooding. It was obvious that overflowing had also occurred at other points upstream from this area, but no official records of other flooding incidents are available.

After the treatment plant was completed and put "on stream" in the autumn of 1954 it was apparent that immediate action by the District was necessary to determine the source of the high flows to the treatment plant. Not only did the high flows result in bypassing raw sewage at the treatment plant but also developed potentially serious health problems, due to the deposition of the raw sewage solids in the areas of overflow. See Plates #1 through #3. Actually a two-way problem developed. Overflow from the sewer added to the rise of the neighboring creek resulting in the deposition of sewage solids along the banks and then, as the flow in the sewer dropped, creek water re-entered the sewer line through the dislodged manhole covers and flowed to the treatment plant.

In the winter of 1954-55 quantitative determination of the infiltration was begun by the office of the Sonoma County Sanitation Engineer on an unofficial basis, inasmuch as the responsibility of the District was not transferred to the County Sanitation Department until July, 1956. In order to gain approximate estimates of infiltration for such a quantitative determination several metering methods were used. It must be understood, of course, that precise measurement was impossible inasmuch as a majority of the gravity lines were not only flowing full but were actually operating under a positive head, thus creating a situation of exfiltration at various locations. Several air bubbler installations were initially utilized as well as the later addition of a Palmer-Bowlus flume and a Kennison nozzle, the nozzle representing a permanent installation which is still in use.

Results of these investigations corroborated the original assumptions of the Sonoma County Sanitation Engineer's Office, namely that the sewer lines were taking in prodigious quantities of winter storm water and ground water; and that, during summer months, extensive exfiltration was occurring as the ground water table lowered.

Concurrent with the investigation of flows, a primary emergency measure called the "Splude Road Overflow Project" was installed by the Sonoma County Sanitation Engineer to relieve the area of overflow of the resulting nuisance caused by putrefaction of the deposited sewage solids. This was accomplished in December, 1956 (as set forth in Report No. 1) by constructing a hydraulic control structure in conjunction with pressurizing eight manholes, all in the trunk line between the treatment plant and the vicinity of Splude Road. (See Plates #4 and #5). The immediate purpose of the hydraulic control structure was to pressurize the trunk line leading to the plant in order that the resulting hydraulic gradient would cause any flows in excess of the existing pumping capacity of the plant (slightly less than 6.0 M.G.D.) to bypass the plant directly into Schell Creek. During periods of high flow, the sewage solids would then be placed in the creek where the high water velocity would carry them away, thus alleviating the problem of settling of the solids on the flood plains surrounding the overflowing manholes, as was the case prior to the construction of this structure. (See Plate #6). The hydraulic control structure in conjunction with the pressurized manholes also prevented flood waters of Schell Creek from draining to the plant subsequent to such periods of heavy rainfall. In addition, if the pumping capacity of the plant were increased to handle the ultimate flows which could be transmitted by this trunk line, the hydraulic control structure was also designed to transmit the total flow to said point with no overflows. This hydraulic control structure was not built until a resolution authorizing such an overflow was passed by the State Water Pollution Control Board No. 2.

The Control Board's requirements stipulate that:

1. ---"None of the following conditions shall occur at any point in the waters of or along the banks of Schell Creek as a result of the proposed waste discharge; Grease, scum or other material of sewage origin; Odors of sewage origin.
2. ---None of the following conditions shall occur, as a result of this discharge, at any point in the waters of the tidal reach of Schell Creek; Depletion of dissolved oxygen below a minimum of 4.0 p.p.m.;

3. ---No sample of the proposed waste discharge collected and analyzed ---shall have a settleable solids concentration of more than 2.0 ml/liter/hr.; . . ."

It should be noted that the above requirements for the waste discharge of the said overflow structure were essentially the same as those required by the Water Pollution Control Board for the Sonoma Valley Treatment Plant. The only additional requirement for the treatment plant is "adequate disinfection". These plant effluent requirements were prescribed by the Water Pollution Control Board in a letter to the Board of Directors of the Sonoma Valley County Sanitation District, dated August 17, 1950.

It became apparent that the infiltration/exfiltration problem had its origin to a large degree in that portion of the sewage collection system encompassed by Local Improvement District I, II and III (See pages SM - 1 to 7 for L.I.D. locations). An investigational program was decided upon for these areas and outlined as follows:

1. Excavation of certain lines throughout the Local Improvement Districts for the purposes of observation and tests. Plates #7 through #10 indicate the manner in which the excavations were made. Collated slides also show some of the excavations.
2. Removal of typical pipe sections from lines exposed by excavation in order to run individual leakage tests on such pipe sections. Collated slides show these pipe sections.
3. Sectioning of pipe joints from pipe removed from excavated sewer lines to ascertain jointing methods used in laying pipe. Sawed portions of pipe are included in Plates #11 and #12 and on the collated slides.

4. Photographing portions of the District sewerage system during various periods of wet and dry weather to establish patterns of sewage and storm water flow. Plates #13 through #22 show manhole interiors and channels during dry and wet weather conditions. Collated slides also show manhole interiors.
5. Design and construction of an automatic recording measuring flume to determine the total trunk line flows upstream from both the treatment plant and the Splude Road overflow, (See Plates #23 and #24) thus making it possible to calculate the amount of overflow in the Splude Road structure.

A description of the investigational program (as covered in collated report #2) is as follows:

"As to the manner in which the selection of lines to be excavated was carried out there was no effort made to isolate and excavate sections thought to exhibit the greatest rate of leakage. The only consideration given to the selection of such sections of line was the necessity of maintaining traffic in the working area. Thus, sections of line were exposed where the neighborhood traffic could either be by-passed around the work or else the street wherein the work was required could be entirely closed.

There was only one section of line exposed where a water test had been given to it prior to excavating same. This section was tested in the belief that a portion of it under a creek had collapsed, this belief being brought about by the inability of District forces to fill the line with water. However, examination of the line subsequent to excavation indicated no structural failure of the pipe. The water was merely leaking through the joints faster than it could be introduced into the pipe from a water tank truck.

The method used in exposing the sewer pipe was that of carefully removing the dirt from the ground surface to a point approximately three inches over the top of the pipe bells by means of a back hoe and then removing the remaining dirt over and around the pipe joints by means of hand digging. The pipe remained firmly in place and with the exception of the area surrounding the joints there was no disturbance of the pipe bedding.

Approximately six joints in the sewer line were exposed at each excavation site, and following such an excavation a test was run on the exposed line. The line was tested by plugging it off at the nearest downstream manhole and introducing dye and water into the nearest upstream manhole or cleanout. The pipe and joints were then observed for signs of leakage, this leakage being readily apparent due to the fluorescent dye employed.

It should be noted that the internal water pressure to which these lines were subjected was very low, in most cases amounting to but a few inches of water pressure."

Plate #7 shows a section of pipe as it appeared prior to hydrostatic testing with dyed water. Plate #8 represents the same section of pipe a few minutes after being filled with dyed water.

It was noted that the holes excavated around the bells became filled with dyed water shortly after the start of the test. The leakage was entirely from the joints; the body of pipe being in sound condition.

In several tests dye was introduced into the water table surrounding the sewer line through sounding wells located within the original trench line. Actual infiltration of ground water was clearly shown by the evidence of the dyed water in the manhole channels. (See Plate #25 and Plate #26)

1. A minimum of two sections of line were uncovered in each Local Improvement District for testing purposes and the lines, for all practical purposes, could be considered as being selected at random.
2. Fifty-eight pipe joints were tested in place, all of which leaked when subjected to minor pressure;
3. An average of one piece of pipe in each section excavated was found in a broken condition. (See Plate #27)
4. Roots were found in the majority of pipe joints so exposed. Plate #28 shows a typical example of root growth in a joint. One particular joint was nine and one-half feet deep and indicates that roots are presently at least that far below the ground surface.

The tests so conducted showed that ground water infiltrating through pipe joints was a major cause of the overflows. To further confirm the extent of joint leakage, sections of pipe were removed and exfiltration tests were conducted on certain individual joints. Quoting from Report No. 2: "The use of the term 'certain individual joints' is used advisedly in this case as it was found that a good share of the joints being removed would merely pull apart at the slightest pressure and that regardless of the extreme care of handling only a select few joints could be salvaged for further testing. In this regard it would be understood that the joints individually tested represent the better joints as found in the exposed lines as the poorer joints would not hold together long enough to have such tests made on them".

Two tests were run on each joint to determine a more accurate leakage rate. The average leakage rate determined in the manner described above amounted to some 27,982 gallons per day per inch diameter of pipe per mile of pipe. Comparing this measured leakage rate to the requirements of the specifications for the original installation of these lines indicates the disparity between the actual leakage rate and the maximum allowable leakage rates. The maximum allowable leakage rate permitted by the specifications was 1000 gals/day/inch diameter/mile of pipe.

By applying the average infiltration rate to the total length of collection system of L.I.D. I, II and III a total of approximately 4.75 M.G.D. of infiltration was theoretically entering the system when ground water had raised in the vicinity of the pipes, see Table I below.

TABLE I

EXPECTED INFILTRATION FROM L.I.D.'S I, II & III WHERE INFILTRATION RATE IS ASSUMED TO BE 27,982 GALLONS/INCH PIPE DIAMETER/MILE OF PIPE

Area	Pipe Size (Inches)	Length of Pipe (Feet)	Length of Pipe (Miles)	Infiltration Per Day (Gallons)
L.I.D. I	6	66,598	12.613	2,117,627
	8	9,888	1.873	419,283
L.I.D. II	6	35,957	6.810	1,143,347
	8	8,086	1.531	342,725
	10	2,139	0.405	113,327
	12	6,750	1.278	429,132
	15	733	0.139	58,342
L.I.D. III	6	3,951	0.748	125,583
			TOTAL =	4,749,366

= Approximately 4.75 Million Gallons/Day

The winter of 1956-57 was relatively dry. However, during one rainy period, the flow in the District (not including the City of Sonoma, or the Sonoma State Hospital) was 5.8 M.G.D. for a particular day. This figure represented the maximum pumping capacity at the treatment plant. Undoubtedly several million more gallons per day were being bypassed, but no measurement of the excess flow could be made. Since normal dry weather flow at this time averaged 0.288 M.G.D. the wet weather flow on this particular day was approximately 20 times greater than the average daily dry weather flow. Because the sewerage system had been in operation less than three years, conclusion was reached that the District was facing a problem of accelerating magnitude. These prodigious amounts of early infiltration were a clue to ever increasing amounts that would follow the inevitable deterioration in the system. Not only was the district system vastly overloaded during rainy weather, but the possibility of expansion of the District sewer service area was out of the question until such time when the overflows could be abated.

Originally two corrective methods of line sealing were considered. These were: (1) The use of a chemical sealant applied internally, and (2) internal grouting. As stated in Report No. 1, neither method was considered feasible:

"The main deterrents to recommending the use of either of these pipe sealing emthods are:

1. Lack of resistance to root growth.
2. Insufficient or no guarantee as to results of treatment.
3. Excessive participation of District forces during treatment.
4. Impossibility of treating trunk lines.
5. High cost of treatment.

The Company offering the chemical sealant method guarantees the work for one (1) year. The Company employing the grouting method gives no guarantee on their work, in fact this Company frankly states the results will range anywhere from good to poor, without any clearly defined reason for either result."

Correction of the line leakage also had a direct bearing on another project under consideration - a trunk line from Madrone Road to the Treatment Plant.

Immediate reduction of infiltration would accomplish several positive results in connection with this trunk line:

(1) "Buy" time in which to adequately plan trunk line construction and financing.

(2) Allow for expansion of the area to be sewered, because the reduction in infiltration would allow the trunk line to be used for sewage instead of storm water.

(3) Permit the use of reasonable pipe sizes in the trunk line design.

Having identified the problem and determined that the existing methods of line sealing would not serve the purpose, the County Sanitation Engineer's office decided to conduct experimental investigations on its own in order to develop a practical method of line sealing. Through 1957 and until the summer of 1958, the investigation was limited to photographing excavated portions of lines as well as manholes under wet and dry weather conditions.

A decision was reached during the early summer of 1958 to seal the leaking lines through the use of an external application of a sealant. The obvious advantage of external over internal sealing methods were:

(1) Bypassing of sewage around line sections under treatment would be unnecessary, and

(2) Intermediate excavation and plugging of steep street laterals to preclude house service lateral flooding would not be required.

It was believed that a sealant would be introduced near the pipe which would surround the pipe by traveling through the voids in the soil. After surrounding the pipe and entering the faulty joints, the sealant would solidify, thus preventing ingress of ground water as well as inhibiting the travel of such water along the pipe line itself.

In June, 1958 a test section consisting of 229 feet of 6-inch vitrified clay sewer line on Davidson Street in El Verano, a portion of the district collection system, was selected for sealing investigation. Applicators fabricated of 3/4 inch pipe were installed on alternate sides of the trench next to the sewer pipe and sealants were subsequently introduced therein. (See Plate #29.)

One half of the line was treated with a hot (360-380° F) sealant of air blown asphalt introduced at approximately 50 p.s.i. (See Plate #30) while the remaining half of the line was treated with a sealant of asphaltic-emulsion (RS-1) applied at ambient temperature and high, but unknown pressure.

Prior to the sealing treatment, hydrostatic tests of this line showed a leakage rate of some 30,850 gallons per day per inch diameter per mile of pipe (gal/day/inch/mile). After treatment the tests revealed a leakage rate of 12,130 gal/day/inch/mile, a sizeable but far from complete reduction of pipe leakage.

High pressure application of both types of sealants resulted in rupture of the soil in a vertical plane parallel to the sides of the originally excavated trench allowing sealants to rise to the ground surface. (See Plate #31). After excavation of part of the test section (See Plates #32 and #33) and evaluation of the results of the test sealing, the use of cold asphaltic emulsion was decided upon.

The emulsion was more economical to apply and far safer to use.

Since the Davidson Street tests resulted in a 60% reduction in leakage rate another test site was selected for study. This was a 95 foot length of 6 inch sewer line on Fifth Street in Boyes Springs. Applicators were again carefully installed on alternate sides of the trench next to the sewer pipe. The exact location of the sewer line was determined by use of a portable pipe detecting instrument which actually located a steel sewer-cleaning rod which had been inserted inside the sewer line to be tested.

Again, cold asphaltic emulsion sealant was used; and it was applied under a low pressure, not exceeding 15 p.s.i. (See Plates #34, #35 and #36)

The "before" water test showed a leakage rate of 696,000 gal/day/inch/mile or nearly twenty-five times greater than the Davidson Street preliminary test. However, the rate after sealing was 543,000 gal/day/inch/mile leaving a net reduction in leakage rate after treatment of only 153,000 gal/day/inch/mile. These figures clearly reveal the magnitude of the infiltration problem.

Excavation of the test section was again made; but, this time the decision to continue or abandon sealing tests had to be made. Examination of the excavations pointed up the fact that the asphaltic emulsion would satisfactorily travel through the voids only when applied with higher pressure. However, the use of higher pressure caused the emulsion to follow paths of least resistance, not necessarily adjacent to the pipe. In view of these negative conclusions and in order to increase flexibility and accessibility in testing, the decision was reached to construct a sample line for further test purposes.

A short length of line (which approximated the poor quality of construction found in the District sewerage system) was installed in the South Park County Sanitation District Yard in Santa Rosa. Extensive testing was begun in July, 1958 to determine if any single asphaltic sealant or combination thereof would do the job. (See Plates #37 through #40). After considerable experimentation together with many partial failures, it was found that an initial gravity application of slow-curing "cut-back" asphalt, such as SC-1, would coat the soil particles in a manner which would allow the passage of the subsequent application of an asphaltic emulsion without a "breaking" of the emulsion prior to complete impregnation of soil surrounding the pipe. The primary sealant would, in effect, prepare an effective path for the emulsion through the voids around and under the pipe. The operating head used on the applicators during these tests consisted solely of the gravity head of the sealants in containers mounted either at ground level or a few feet above the ground.

Because the encouraging Santa Rosa tests were conducted in an adobe type soil, the conclusion was reached that positive results could be achieved in any soil type. In October, 1958 another field test was initiated in Boyes Springs employing the "new" Santa Rosa technique. As stated in Report III, this new technique was as follows:

"1. The applicators were installed, not as previously alongside the sewer pipe, but merely in the original trench area over the sewer pipe with the lower end of the applicator approximately ten inches (10") above the top of the pipe. This type of applicator installation greatly simplified this phase of the work, for no exact determination of the location of the sewer line was necessary and only minimum caution had to be practiced to avoid damaging the said sewer lines.

2. After installation of the applicators a short, sharp jolt of the primary sealant was introduced into the applicators at pressure of from 50-60 p.s.i. This pressure "jolting" was found necessary to split the type of impervious soil found in the hilly areas of Boyes Springs. As soon as the pressure dropped in the applicator line - the time involved in this procedure was measured in seconds - the pressure application was immediately halted.

3. The primary sealant, after the pressure "jolting" was introduced by gravity feed from 50 gallon drums mounted on wooden cradles which in turn rested on the ground to one side of the road in such a manner as to

be out of the way of vehicular traffic.

4. After sufficient primary sealant was introduced the secondary asphaltic emulsion was applied through the same applicator and in the same manner as the primary sealant, however, no initial pressure was used in this stage of treatment.

Internal photography of the line (See Plates #41 and#42) as well as subsequent excavation corroborated the growing feeling that this type of external sealing process could be successful. With the qualitative results having been determined, it was decided to extend the testing into the area of quantitative determinations - that is, how much material would be required to treat a given length of line. In April, 1959 a 265 foot length of 6-inch vitrified clay sewer line on Arroyo Avenue in Boyes Springs together with approximately 100 feet of 4-inch house service was treated (See Plates #43 through #46). The steep terrain precluded the possibility of practical hydrostatic testing. Careful measuring of the amounts of sealants introduced into the applicators indicated that 1.5 gallons of each material per linear foot of line represented an optimum application. However, later sealing on an adjacent street (Central Avenue) proved that the 1.5 gal/ft. quantity was not valid. Soil conditions bedding and backfill methods and subterranean voids were found to vary greatly, and this would cause the "dosage" to vary greatly. (See Plate #47)

The Arroyo Avenue test did result in the learning of several new facts and techniques. These pertained to: length of travel of sealants; effects of dry soil on sealants; effects of wet soil on sealants; techniques for plugging large openings in sewer lines; and the importance of sealing house service sewers. (In most cases the originally installed house service sewers were in worse shape, if possible, than the street laterals. See Plate #48)

In midsummer of 1959, the County Sanitation Engineer proposed to treat approximately one and one-half miles of badly leaking sewer line in the Boyes Springs area prior to the winter rains. By comparing the approaching wet weather flows with photographic records of past winter flows and past dry weather flows a decision could be reached by the Board of Directors as to the practicality of embarking on a full scale sealing program. At the same time, it was suggested that the line sealing process be patented (See attached Patent) in order to preclude the possibility of the District's paying royalities or fees for use of a method which the District itself developed. By January 1, 1960, a total of only 2850 feet of line had been treated. A three man crew, using simple hand tools together with a water tank mounted on a dump truck and an air compressor with hand air tools, had accomplished this amount of sealing prior to any substantial winter rains. However, it was discovered that the cold weather of late autumn and early winter hampered progress because freezing temperatures caused the asphaltic emulsion to "break" in the applicator piping and barrels.

In early March, 1960 a series of "bucket" tests was inaugurated at the South Park Corporation Yard. (See Plates #49 through #52). A series of four 5-gallon buckets was used. Each bucket was fitted with a section of 4-inch vitrified clay pipe which had been cut in order to simulate broken sewer lines. Two buckets were filled with wet sand and two with dry. Quart cans were semi-submerged into the sand and sealants introduced into these quart cans.

By varying the type of sealant and by the experimental use of additives such as lye and salt, it was possible (after cutting open the buckets) to determine the effectiveness of the sealing as well as the control of sealant "breaking".

It was concluded that the application should consist of "pre-treatment" with SC-1 followed by RS-1 treatment. "Breaking" control would be effected by the use of salt water.

Because the rainy season was late in arriving, it was possible to increase the total treated length to 3242 feet as of April 1960. Since the treated sections of the sewer lines were those portions lying within the road rights of way and not on private property, it became necessary to separately identify the source of infiltration. Quoting from Report V: "In this respect some provisions had to be made to differentiate between the infiltration of ground water into the shallow house service sewer lines lying in private property - which were not treated - and the deeper street laterals - which were treated. Such a differentiation in source of infiltrating water was obtained by the installation of several sounding wells adjacent to the various house service sewer lines tributary to the treated street laterals. These wells enable a determination of the water level surrounding the house service sewers to be made, and obviously, when the water table recedes below the shallow house service sewers, any surplus water observed in the street laterals must have originated through leaks in the deeper lines".

By comparing the 1959 photographs with those taken in 1960 - in spite of heavier 1960 rainfall - a decrease was noted in compared sewage flows. Additional observations and photographs made several days after actual rainfall showed that the shallow portions of the house service lines between the property lines and houses drained into the surrounding soil rapidly. District flow charts showed the high early quantities of ground water infiltration due to the shallow laterals and then subsequently reflected the long-time effects of deeper infiltration into the street mains and laterals. Because the line sealing activity thus far was primarily for the correction of deeper line leakage, repair or replacement of house service sewer lines was anticipated. Admittedly, this was a large undertaking; but necessary to reduce infiltration to an acceptable value.

Calculation of line sealing costs during this experimental period were limited to material costs and amounted to less than fifty cents per foot. Faced with the potential task of sealing thirty-six (36) miles of mains and street laterals, the County Sanitation Engineer requested and received authorization from the Board of Directors to expand the two man work force to a six man unit and also to purchase a wagon drill, air compressor, and two trucks to expedite the work.

Utilizing the enlarged work force and mechanical equipment, the County Sanitation Engineer was able to report the sealing of a total of 2.2 miles of sewer line as of December, 1960.

By installing "weep" pipes in all manholes approximately six inches over the lines, along the treated lines, the sealing crew could observe the ground water level over the sewer lines. (See Plate #54) Encouraging signs became evident as early winter rains saturated the ground. For example, the 6 inch Las Lomas Road line south of Arroyo Avenue which flowed half full during presealing winters now showed only a trickle of water. Rainfall totals and ground water conditions for Plates #53 and #54 were approximately equal.

Hydrostatic tests of the Las Lomas Road line north of Arroyo Road showed a leakage rate of less than one gallon per minute - as opposed to a presealing rate of well over 200 gallons per minute. (This figure is based on the unloading rate of a water tank truck which could not fill the lines.)

In December, 1960, the County Sanitation Engineer recommended the adoption of a five year line sealing program in which approximately seven miles of sewer line would be sealed each year at an estimated annual cost of $63,000 per year. Later experience proved this proposal to be somewhat optimistic in both length and cost. In February 1961, the District Board of Directors passed a resolution which stated the District's intent to repair five miles of sewer line during the 1961-62 fiscal year.

In reporting the status of the Splude Road bypass operation to the San Francisco Regional Water Pollution Control Board in May, 1961, the County Sanitation Engineer listed a total of 3.6 miles of sewer sealed or being sealed. The total included 12,466 feet of street laterals, 4,163 feet of house service sewers located between the street laterals and property lines and 2,293 feet of house service sewers located between the property lines and buildings served. The latter category represented approximately 100 house services on private property; and these services had been hand excavated and repaired.

In addition, the Splude Road overflow had recorded a total of 77.8 hours of overflow time during the period of between December 1, 1960 and March 26, 1961. Total rainfall for this period was 14.0 inches.

Reporting to the Regional Water Pollution Control Board again in late October, 1961, the County Sanitation Engineer observed that an additional 1.5 miles of sewer line had been sealed or repaired.

It became apparent at this time that the need for repairing creek crossings was equal in importance to the line sealing. Wet weather creek flow was introducing substantial quantities of storm water into the system due to the poor conditions of the crossings. However, the reconstruction of the crossings was time consuming. The 534 feet of creek crossings replaced by the line sealing crew as of October, 1961, represented an expenditure of time which would have resulted in the sealing of a considerably greater length of street laterals and mains.

The County Sanitation Engineer reported a sharp increase in dry weather flow during 1960-61 as compared to the 1959-60 dry weather flow (See Table I, Collated Report 8). Although no definite conclusion was drawn, the unofficial inference was that the increase was due to a reduction in exfiltration and directly attributed to line sealing and repair.

As of March 1, 1962 the total lengths of line sealed and repaired were as follows: 17,113 lineal feet of street laterals; 5,317 lineal feet of house service sewers located between the street laterals and property lines; and 3801 lineal feet of house service sewers located on private property and miscellaneous creek crossings. Costs for this amount of line sealing were reported as $101,857.86 of which $60,183.54 capital equipment. The salary component of the total cost actually includes the salaries of all personnel assigned to the collection system; and, therefore, it includes some routine maintenance costs which were not separated from the line sealing costs. A realistic estimate of the division of line sealing and routine maintenance would have been in the order of $42,000 and $18,000 respectively.

At this time it was projected that in 1968, of the 35 miles of mains plus approximately 10 miles of house services located on private property in the District, a total of 38.6 miles of line would have been sealed or repaired. This would represent the point at which the Splude Road bypass could be eliminated. Further expenditure of funds would probably not be justified beyond this level of correction. Projecting the cost figures against the planned total length to be sealed, and comparing them with conservatively calculated cost of replacement - the only alternative to sealing - the County Sanitation Engineer produced the following costs $500,000 and $2,500,000, respectively.

Subsequent to March 1, 1962, the lengths of line sealed and repaired areas shown in Table II.

TABLE II

Lengths of Repaired or Sealed Sewer Lines (Lin. Ft.)

Dates	Street Laterals	House Service Sewers within Street or R/W	House Service Sewers on Private Property	Creek Crossings
3/1/62 to 6/1/62	8722	2391	859	694
6/1/62 to 12/1/62	6442	897	70**	230
12/1/62 to 6/1/63*	6418	3485	66**	—
6/1/63 to 12/1/63	492	532	152	—
12/1/63 to 6/30/64	8003	925	3698	—

*840 Ft. Street laterals were removed and replaced with new pipe during this period

**Individual house service - not lineal ft.

As a note of special interest, the United States Patent office granted a patent for this process to Marshall M. Wallace and Eugene B. Dykes, assignors to the County of Sonoma, on April 9, 1963. (See attached Patent)

The progress of the line sealing program up to February 1, 1965 covered some 14 miles of District sewer line. This length included: 47,190 feet of street laterals; 10,902 feet of house services located between the street laterals and property lines; 1600 feet of creek crossings; and 15,050 feet of house service sewers located between the property lines and the buildings served. The latter length represents some 341 house services replaced. Also, the requirement of elimination of the Splude Road bypass no longer hinged completely on the line sealing program. Three additional factors which would aid the elimination were introduced. These were: expansion of the treatment plant, construction of settling structures, and pressurization of the outfall.

The latest report on the Splude Road bypass, dated July 28, 1965 showed additional sealed or repaired lengths as follows: 3278 feet of street laterals; 587 feet of house services located between the street laterals and property lines; and 3433 feet of house services on private property. The latter length of pipe represents 61 house service sewers on private property.

HB - 21

Plate #1 - Normal dry weather flow in the channel of a typical flood plain manhole.

Plate #2 - Wet weather overflow from same manhole shown in Plate #1. Flowing water is issuing from manhole located in the center of the picture.

Plate #3 - Deposition of solids on area surrounding same manhole as shown in Plates #1 and #2 after flow has subsided. Dislodged manhole cover drained flood water into manhole as flow subsided.

Plate #4 - Recorder, mounted at top of cylindrical overflow structure, indicates periods of overflow.

Plate #5 - Construction of pressurized manhole. Concrete being placed around manhole reinforcement in a calculated amount which exceeds the internal pressure of the manhole. Note specially fabricated pressurized manhole frame and cover.

Plate #6 - Turbulent water at rock headwall marks the submerged point of discharge of the Splude Road overflow into the main thread of the stream. Prior to the installation of the Splude Road overflow structure vegetation shown was covered with deposited solids after periods of flooding.

Plate #1

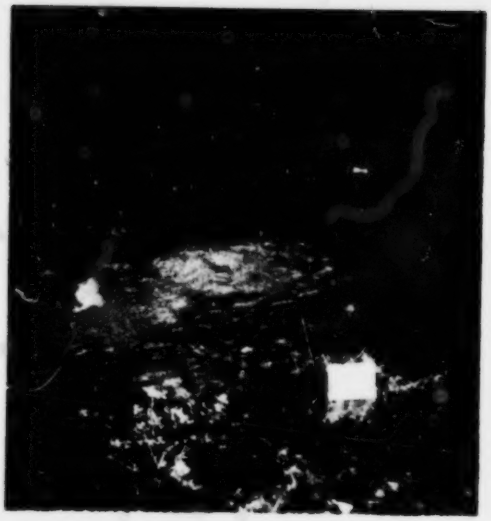

Plate #2

Plate #3

Plate #4

Plate #5

Plate #6

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Plate #7

Plate #8

Plate #9

Plate #10

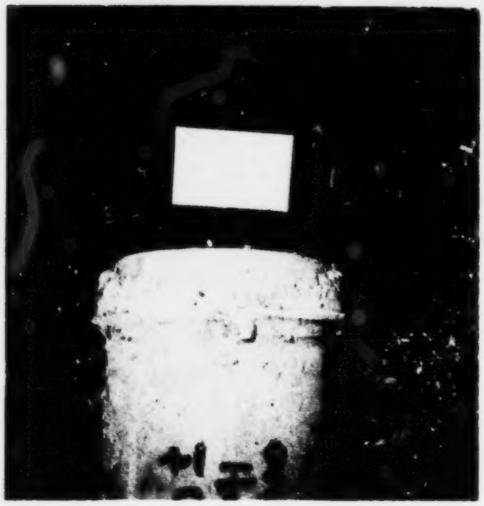

Plate #11

Plate #12

Plate #7 - Excavation of 6-inch vitrified clay, mortar joint, sewer line in L.I.D. II, prior to hydrostatic test with dyed water. Note dry condition of trench bottom.

Plate #8 - Same line as shown in Plate #7, several minutes after start of hydrostatic test. Note pools of dyed water in pockets near pipe bells.

Plate #9 - Section of excavated 6-inch vitrified clay, mortar joint, sewer line in L.I.D. I, shortly after start of hydrostatic test with dyed water. Note jets of water spraying from joints.

Plate #10 - Section of excavated 6-inch vitrified clay, hot poured C.P.I. joint, sewer line in L.I.D. III, shortly after start of hydrostatic test with dyed water. Travel of dyed water through uncompacted fill and voids under pipe visible from joint at center to joint at bottom of picture. Note jet of water issuing from bell which cracked because of improper bedding.

Plate #11 - Underside of section of 6-inch vitrified clay, mortar joint, sewer line removed from trench in L.I.D. II. Thin fillet of mortar resulting from poor penetration of mortar into annular space in pipe bell. Fingerprints in mortar indicate improper method of joint construction. Specifications called for complete filling of space with mortar tamped by hardwood stick.

Plate #12 - Sawed portions of 6-inch vitrified clay, mortar joint, sewer line removed from L.I.D. I. Note thin fillet of mortar in bell. Thick ring of infiltrated dirt shown in left-hand section.

Plate #13 - Dry weather flow in manhole T-74. Note air bubbler measuring device mounted on right hand side of the manhole.

Plate #14 - Wet weather flow in manhole T-74. High water mark for this particular storm visible in the upper right hand corner of the picture.

Plate #15 - Dry weather flow in manhole T-26. Manhole is at confluence of the City of Sonoma and the District systems. Purplish cast to the raw sewage is due to wine waste. Note the air bubbler measuring device at right hand side of picture.

Plate #16 - Wet weather flow in manhole T-26.

Plate #17 - Dry weather flow in manhole 1-114.

Plate #18 - Wet weather flow in manhole 1-114. Water is entering manhole through upper tee of manhole inlet, which is partially plugged with sewage solids.

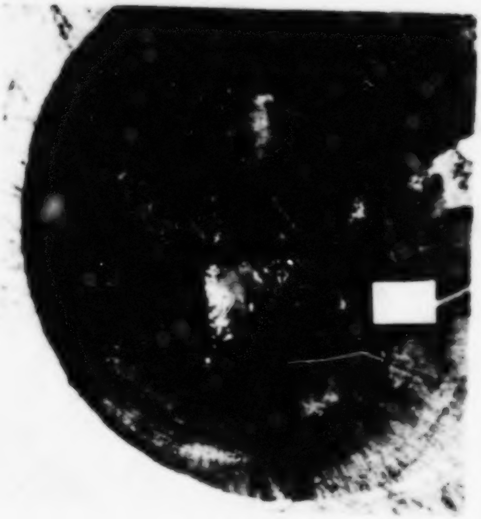

Plate #13

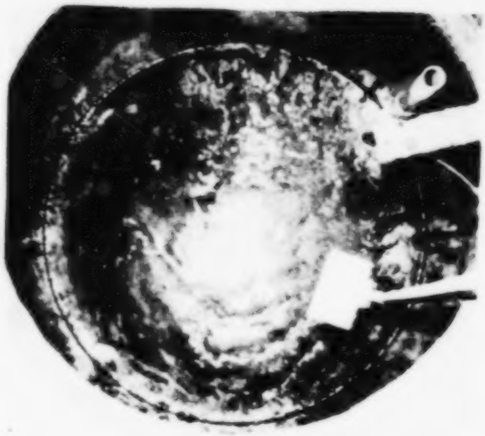

Plate #14

Plate #15

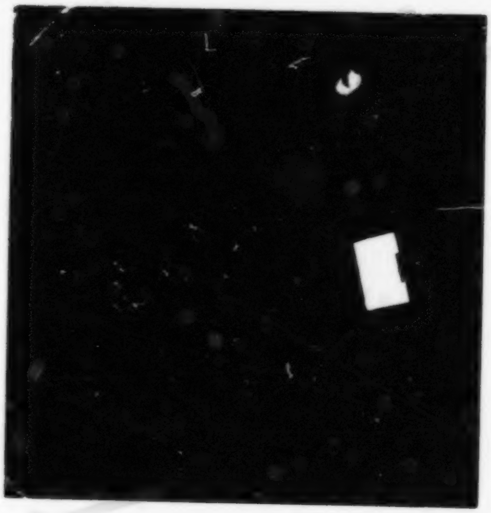

Plate #16

Plate #17

Plate #18

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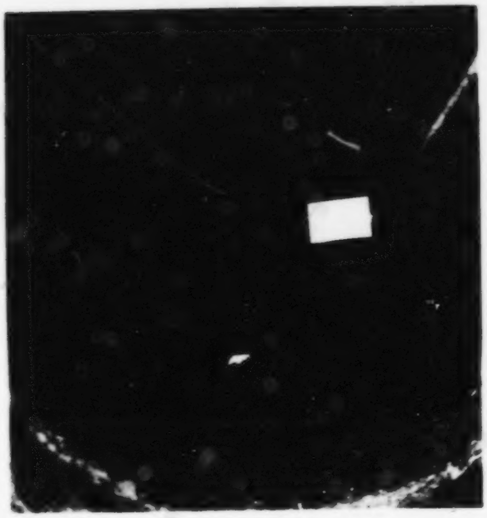

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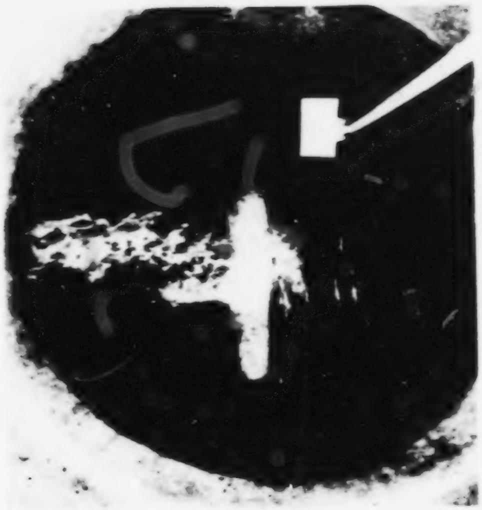


Plate #20

Plate #21

Plate #22

Plate #23

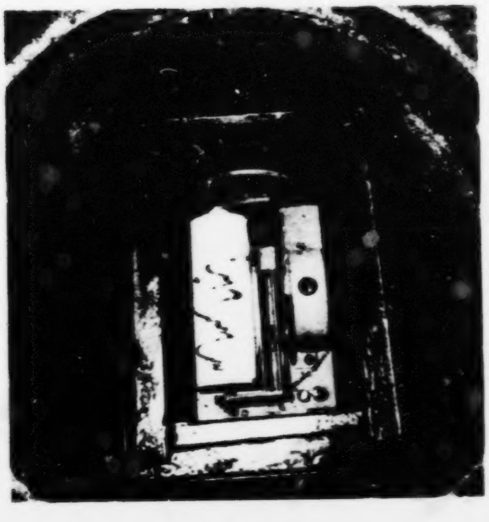


Plate #24

Plate #19 - Dry weather flow in manhole 1-14.

Plate #20 - Wet weather flow in manhole 1-14. Flow entering upper tee of drop manhole inlet at left.

Plate #21 - Dry weather flow in manhole T-92. Note buildup of solids on left hand shelf.

Plate #22 - Wet weather flow in manhole T-92. Washed off shelves are evidence of higher flows than shown.

Plate #23 - Measuring flume with recording meter mechanism installed in flow channel. Scow float under frame at center transmits variation in flow depth. Wheel in left foreground forces floating solids in stream to flow beneath float. Air bubbler device in right foreground is utilized for calibration of depth recorder.

Plate #24 - Recorder mounted in manhole containing the automatic recording measuring flume.

Plate #25 - Evidence of infiltration shown by dyed stream of water in channel of manhole 2-47. This dye was introduced into the sounding well several hundred feet upstream from this manhole, 22 seconds before this photograph was taken indicating the extent of the infiltration of ground water into the line.

Plate #26 - Leaking manhole base. Plugged line at right of picture was being tested with dyed water. The water exfiltrated from this line and infiltrated into the line which runs through the main channel of the sewer, indicating that the dyed water had exfiltrated through breaks in one line and infiltrated through breaks in another line as well as leaking in through the manhole base.

Plate #27 - Break in 6-inch vitrified clay line in the vicinity of manhole 2-47. This is a typical break of the sewer line in close proximity to the manholes and is a result of differential settlement. In order to avoid this type of pipe failure, the County of Sonoma Sanitation Department Sewer Construction Standards now includes the requirement for flexible couplings within 39 inches of the manhole.

Plate #28 - Root growth surrounding and entering pipe joint. Date on photograph indicates growth took place over a period of less than four years since 1953-54 installation.

Plate #29 - Alternating locations of applicators in Davidson Street.

Plate #30 - Hot air blown asphalt rig prior to hoses being attached to first two applicators, thus maintaining the necessary high temperature between 360-380° Fahrenheit. Use of two hoses provides a circulating effect through the applicators.

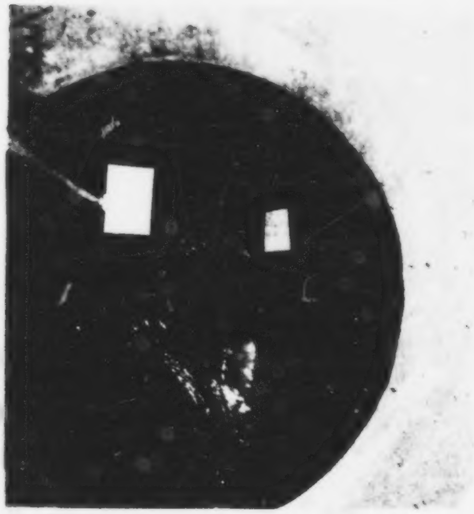


Plate #25

Plate #26

Plate #27

Plate #28

Plate #29

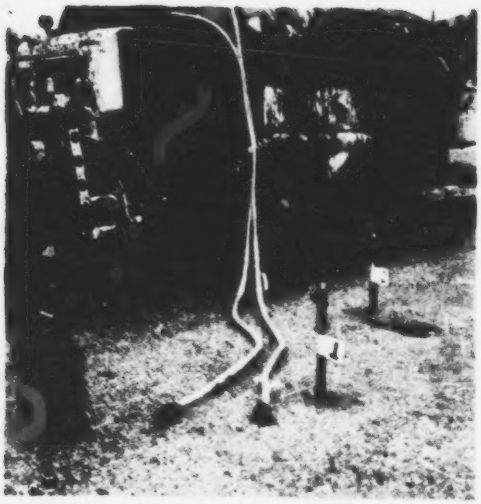
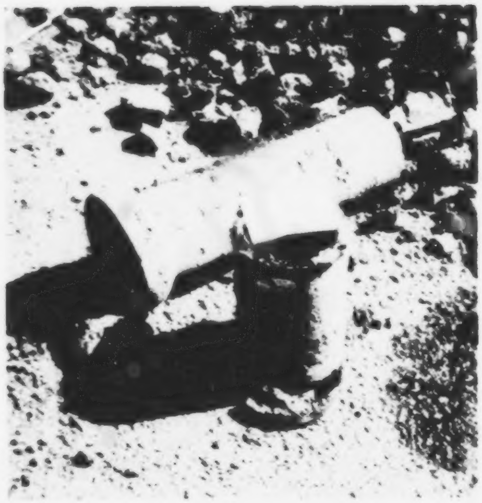


Plate #30

Plate #31

Plate #32



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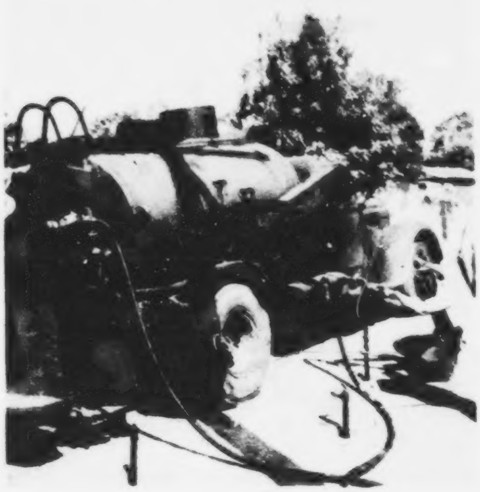

Plate #34

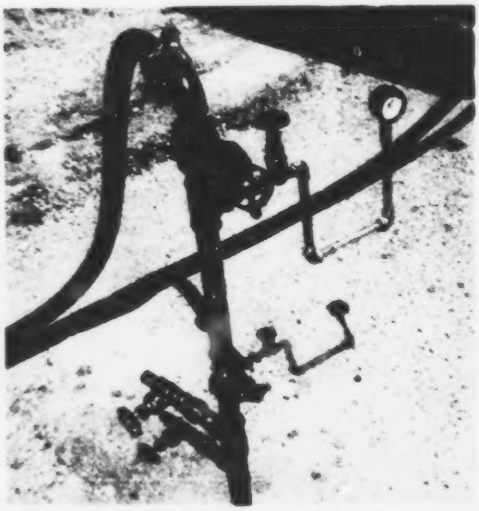

Plate #35

Plate #36

Plate #31 - Cracks in pavement resulting from high pressure application of sealant. This trench is approximately 5 to 6 feet deep and is split from the 5 to 6 foot depth to the surface. Pencils have been inserted in the cracks in the pavement and accumulations of asphaltic material at the surface are visible.

Plate #32 - Asphaltic material in joint. Hot asphaltic material immediately set up as it contacted cold moist soil. Sealing of pipe was not completely effective because material set up along the trench lines which has cracked through to the surface.

Plate #33 - Results of hot asphalt application in one of the test section joints. While lack of mortar bond between the bell and spigot is sample of poor construction, it allows for good sealing with hot asphalt.

Plate #34 - Rig used in pressure application of cold asphaltic emulsion sealant.

Plate #35 - Closeup view of applicator showing pressure controls.

Plate #36 - Application of cold asphaltic emulsion under low pressure. Note alternating positions of applicators. Sewer cleaning rod visible entering manhole.

Plate #37 - Excavation at South Park Corporation Yard test site. Applicator pipe extends down into a dull black area which is SC-1. Shiny black area below is RS-1. SC-1 eventually sets up as volatile portion dissipates.

Plate #38 - Test section of line in which only SC-1 application was used.

Plate #39 - Application of SC-1 only. The ability of SC-1 to bind the individual granular particles is shown very clearly. The binding of the particles provides paths for the RS-1 to travel through the material.

Plate #40 - Water test conducted in a trench at South Park Corporation Yard in which both SC-1 and RS-1 application had been used. The excavation at center of trench was filled with water with no significant loss after 15 minutes, showing effectiveness of sealants.

Plate #41 - Internal photograph of 6 inch vitrified clay line showing root growth and sealant in pipe joint. Prevalence of growth in these internal photographs led to the process of using a porcupine for cleaning the line before and after sealing. Subsequent application of copper sulfate in the line kills the root growth which existed prior to treatment. Little or no subsequent root growth after this treatment is anticipate in the treated joints.

Plate #42 - Internal photograph of 6 inch vitrified clay line subsequent to cleaning line with porcupine. Ring of asphalt visible in the joint closest to the camera indicates effectiveness of treatment.

Plate #37

Plate #38

Plate #39

Plate #40

Plate #41

Plate #42

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Plate #43

Plate #44

Plate #45

Plate #46

Plate #47

Plate #48

Plate #43 - Excavation after treatment of 6 inch vitrified clay line on Arroyo Ave. Treatment is two stage, using SC-1 followed by RS-1.

Plate #44 - Excavated joint of 6 inch vitrified clay line on Arroyo Avenue. Asphaltic material visible underneath and along the spring line of the pipe indicates that sealant has followed in the voids caused by water flowing below and alongside the pipe.

Plate #45 - Length of 6 inch vitrified clay pipe on Arroyo Avenue after excavation. Picture shows same section of pipe as in Plate #44 rolled to one side to show asphaltic material in the trench beneath and up to the spring line of the pipe. This photograph shows that the asphaltic sealant travels only where water travelled around the pipe. The impervious nature of the set-up asphalt can be shown by the water lying in the trench line in the center of the picture.

Plate #46 - Excavated house service on test line on Arroyo Avenue showing travel of sealant along house services. No applicator was installed in this house service. Sealant followed along the trench line and entered into the house service through the broken joint. Large amounts of sealant in the line indicate this break existed. This amount of flow in the line led to further study as to the location of the distance between applicators in various soil conditions.

Plate #47 - Example of improper bedding and backfill methods showing basalt block on crown of pipe. Sewer line runs from the bottom of the picture up to the top of the picture. The one joint of the sewer can be seen immediately below the white card in the picture. The presence of voids in this rocky terrain indicates how the amount of sealant used can vary greatly in this type of soil. Applicator drilled into this type of boulder is hindered from spreading of asphaltic material in the trench. Condition is corrected by moving applicator short distance.

Plate #48 - Example of poor construction of house service sewer.

Plate #49 - 4 inch vitrified clay pipe used in asphalt bucket tests at South Park Corporation Yard prior to filling bucket with aggregate.

Plate #50 - Four test buckets prior to being filled with aggregate and asphaltic material at South Park Corporation Yard.

Plate #51 - Buckets after being filled with soil during asphalt bucket test at South Park Corporation Yard. Asphalt was added through the quart oil cans that are visible at top of the specimen buckets.

Plate #52 - Section of bucket cut away showing asphalt impregnation in the soil in the bucket. South Park Corporation Yard test.

Plate #53 - Flow in manhole 90 prior to sealing the Los Lomas Road line with asphaltic material. Los Lomas line enters manhole diagonally from the left.

Plate #54 - Flow in 6 inch Los Lomas Road line through manhole 90 after sealing. Flow in the Los Lomas Road channel considerably reduced.

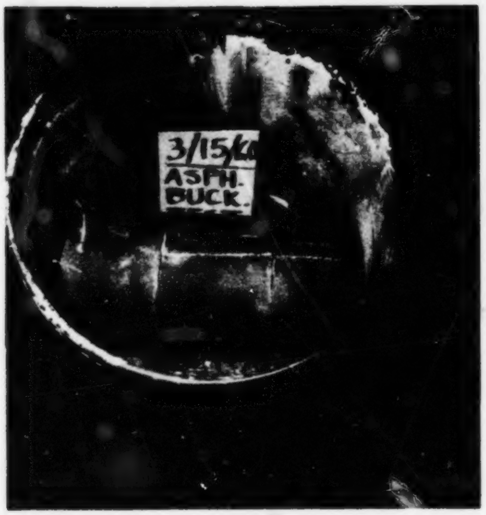


Plate #49

Plate #50

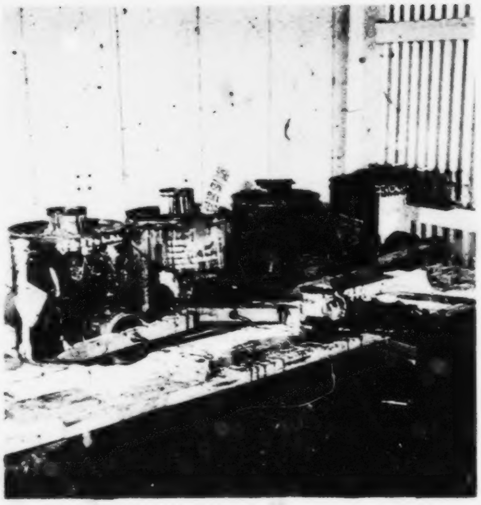
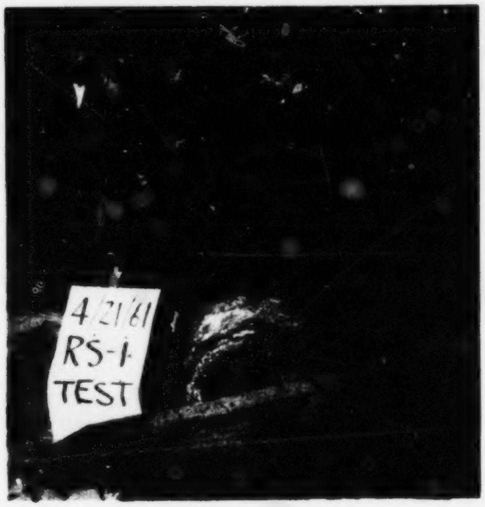


Plate #51



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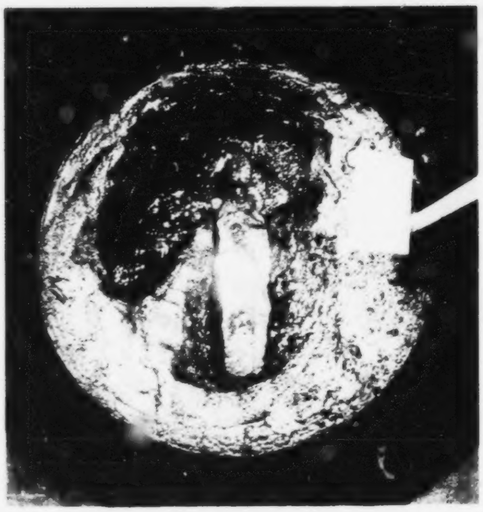

Plate #53

Plate #54

Plate #55

Plate #56

Plate #57

Plate #58

Plate #59

Plate #60

41

Plate #55 - Sewer cleaning operation, prior to attachment of porcupine (center foreground) to cleaning rod.

Plate #56 - Technician locating sewer center line using electronic pipe finder.

Plate #57 - Drilled hole near shiner location. Applicator shown in background. Chalk mark "60" represents maximum depth (in inches) for drilling.

Plate #58 - Maximum drilling depth being marked on drill bit.

Plate #59 - Drill rig used in drilling applicator holes.

Plate #60 - Six-inch diameter hole at top of applicator hole. This hole facilitates connection of applicator to horizontal pipe.

Plate #61 - Loose material being blown from drilled hole by use of ½-inch pipe connected to air line.

Plate #62 - Applicator shown disassembled (bottom of picture) and assembled (top of picture).

Plate #63 - Applicator installed in hole. Temporary pipe cap affixed to top of applicator protects applicator and prevents dirt from entering.

Plate #64 - Horizontal installation of pipes in shallow ditches. 12-inch storm drain terminates at concrete headwall at right hand center of picture. Applicators have been installed to straddle this storm drain.

Plate #65 - "Side-by-side" comparison of methods of installing horizontal pipe in roadway.

Plate #66 - Overall view of sealing installation in which horizontal pipes were installed on roadway surface and "taped" down.

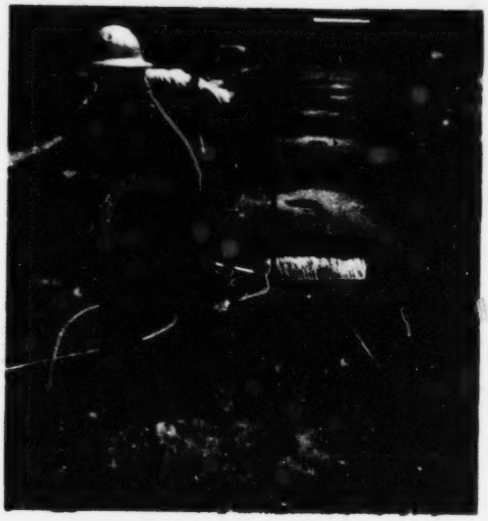

Plate #61

Plate #62

Plate #63

Plate #64

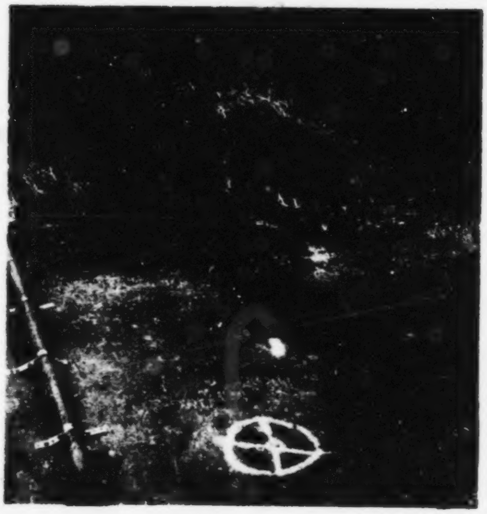

Plate #65

Plate #66

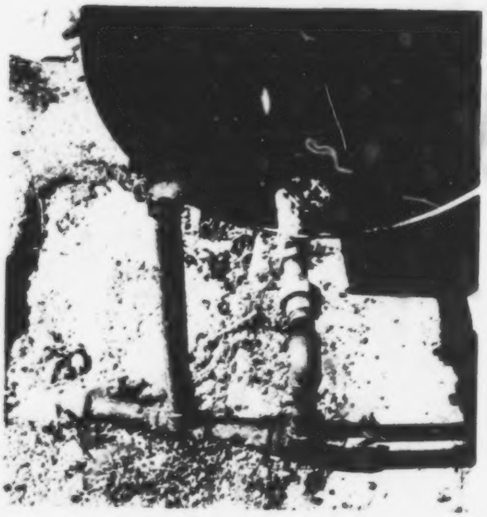

Plate #67

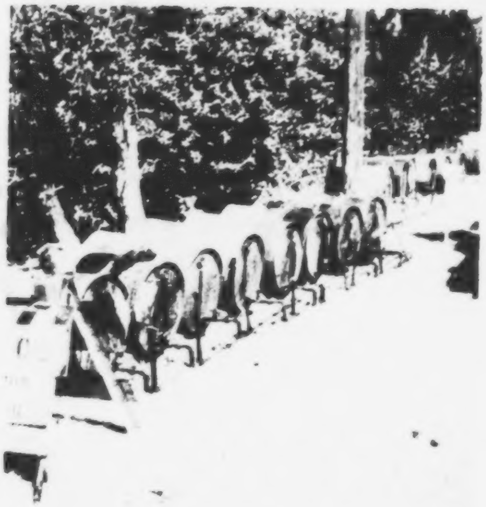

Plate #68

Plate #69

Plate #70

Plate #71

Plate #72

Plate #67 - Riser pipe and barrel valve installation.

Plate #68 - "Stacked" barrels. Note long runs of piping used to deliver asphaltic material to narrow easement.

Plate #69 - Piping used to deliver asphaltic material to applicators in narrow easement in which barrel filling would be impossible.

Plate #70 - Asphalt trailer used to fill drums.

Plate #71 - Application of SC-70 into stand pipe at 40 psi. in order to "crack" backfill around sewer line.

Plate #72 - Removal of waste RS-1 clumps from channel in manhole.

Plate #73 - Soil testing by means of hand auger. Sampler is driven into soil by raising and dropping weight.

Plate #74 - Overall view of test site in Alley #4 in Forestville C.S.D., water tank truck in background is located at cleanout.

Plate #75 - Weep pipe in manhole. As asphaltic material builds up head outside manhole, additional lengths of weep pipe are coupled inside manhole to facilitate determination of level.

Plate #76 - Overall view of test site on Graton Road, Occidental C.S.D. Asphalt trailer shown is hooked to District pickup truck.

Plate #77 - Evidence of heavy asphalt leak visible in 30-inch concrete drain.

Plate #78 - Hydrostatic test water leaking through coupling between concrete pipe and asbestos cement pipe. No gasket in coupling on concrete pipe.

Plate #73

Plate #74

Plate #75

Plate #76

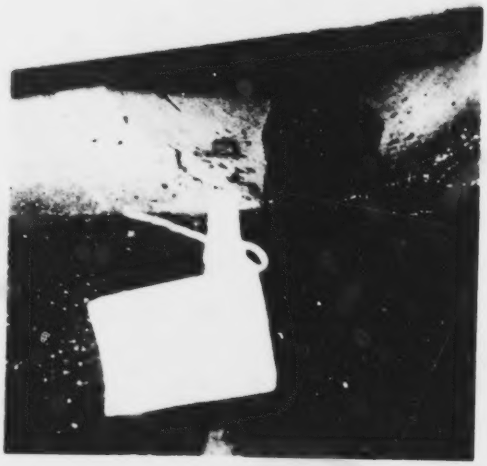

Plate #77

Plate #78

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Plate #79

Plate #80

Plate #81

Plate #82

Plate #83

Plate #84

Plate #79 - Test line installed at Bodega Bay. Joints were deliberately constructed to cause leaking to occur.

Plate #80 - Example of pipe used in Bodega Bay test line. Oakum joints were covered with mortar, but no attempt was made to ram mortar tight.

Plate #81 —Installation of applicators on test line at Bodega Bay. Note proximity of test installation to water. Under high tide (greater than 6.0 feet) entire visible beach is inundated.

Plate #82 - Sight well installation at Bodega Bay test site. Visible in foreground are sumps. Recorder was installed on right-hand sump to record tide fluctuations. However, inundation under extremely high tides reduced value of the recorder.

Plate #83 - Hydrostatic test on sample of construction used at Bodega Bay test line. Several tests were necessary in order to perfect technique of constructing leaking line.

Plate #84 - Device used for determining relation between tidal effect and infiltration. Rise in tide was measured in perforated sump (left side), while actually infiltration was collected in measured container lowered into right hand sump. Downstream end of test line visible in right hand sump.

Plate #85 - Five tests conducted at Bodega Bay site to determine flow of asphaltic materials in various media.

Plate #86 - Upper portion of Cecelia Drive test site, Sonoma Valley C.S.D. looking east. Diagonal dark areas are applicators which have been paved over.

Plate #87 - Lower portion of Cecelia Drive test site, looking west. Note installation of barrels at curbs.

Plate #88 - Excavation of test line at Forestville. Asphaltic material visible approximately one foot above crown of pipe.

Plate #89 - Exposed pipe, excavated after sealing at Forestville. Asphaltic saturation of trench surrounding pipe visible.

Plate #90 - Joint of pipe exposed after sealing at Forestville. Travel of asphaltic material around joint of pipe evident.

Plate #85

Plate #86

Plate #87

Plate #88

Plate #89

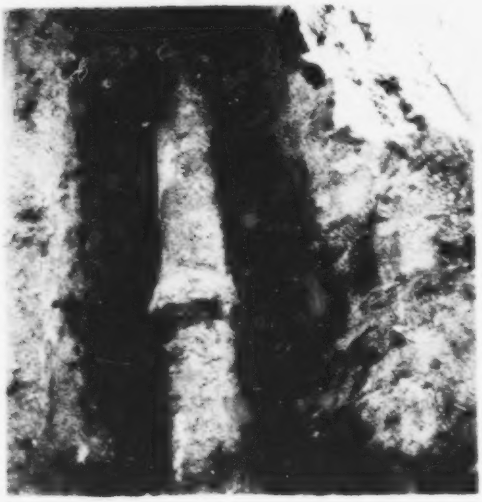


Plate #90

Plate #91

Plate #92

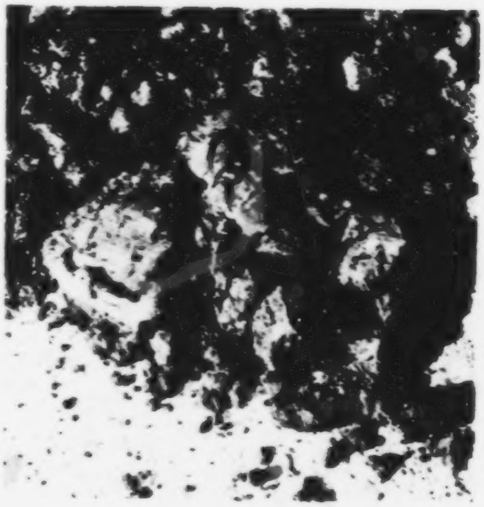


Plate #93

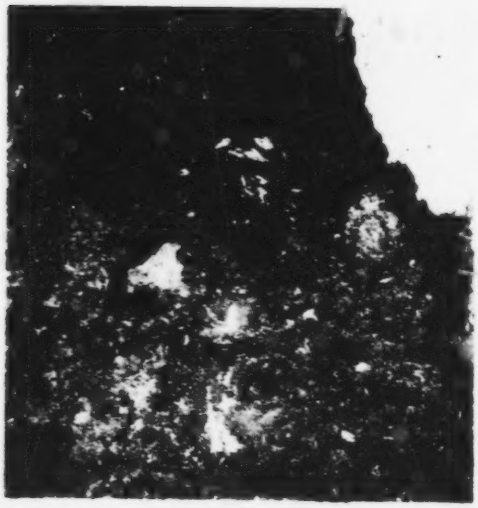


Plate #94

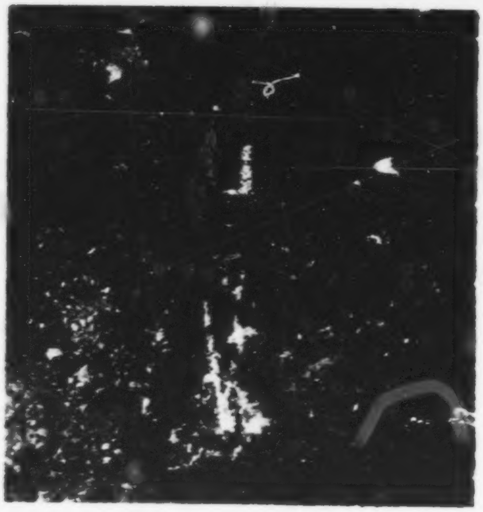


Plate #95

Plate #96

Plate #91 - Excavation of house service connection on test line at Forestville. Dark areas indicate asphalt penetration into backfill. Note pockets in which asphaltic material had filled voids.

Plate #92 - Impregnated material excavated from sealed line at Forestville.

Plate #93 - Closeup view of excavated material. Note free-running RS-1.

Plate #94 - Excavation of test line at Occidental C.S.D. Shovel blade at top of picture is resting on top level of impregnated backfill.

Plate #95 - Closeup of joint in concrete sewer line at Occidental. Typical accumulation of free-running RS-1 evident at joint.

Plate #96 - "Evidence" of diluted asphaltic material issuing from old cut in oak tree trunk. No chemical analysis of material has been made, thus it is doubtful that this is truly an asphaltic material.

FIELD TESTING

While the preceding section of the Report deals with the history of the development of the external asphaltic sealing method of repairing leaking sewer lines, this section of the Report pertains to the current techniques employed in the utilization of this sealing system. These techniques will be presented, insofar as possible, in the same logical order as practiced in the field. Various color plates pertinent to the field procedure are keyed to the text of this section.

Testing: In this category are included: testing of large areas to isolate those areas demanding closer study and the need for more refined testing; and post-sealing testing.

The following is a brief description of each of the procedures:

Testing of larger areas, as practiced by the Sonoma County Sanitation Department consists of two steps: first, visually observing sewage flow in sewer manholes located in the areas under study. Such observations are made during all possible combinations of sewage flow and extraneous storm water flow. Second, excavating suspected sections of badly leaking lines to ascertain the reason for such leakage.

This latter step involved: excavating the line without disturbing it (see Plate #7); observing the condition of the line; internal pressure testing using dyed water (See Plates #8, 9 and 10) and removing sections of the pipe for study. (See Plates #11 and 12)

The Sonoma County Sanitation Department's early experimentation with internal sewer line photography (See Plates #41 and 42) indicated that dry weather photography was of limited value in determining the types of sewer line failures that were prevalent in the Sonoma Valley County Sanitation District. The same limitations would presumably apply to dry weather closed circuit T.V. viewing. For this reason internal sewer line observations by camera was not extensively employed, and no T.V. viewing was utilized.

Presealing testing of the sewer line basically consists of determining infiltration rates through exfiltration. Hydrostatic testing is employed because of the ease of performing "before and after" tests. Rather than attempting measurement of actually infiltrated water, the Department uses the hydrostatic test because this test is not directly dependent upon fluctuations in the surrounding water table. A brief summary of the testing procedure as stated in Section 15-05 (c) of the County of Sonoma Sewage System Standards is as follows: "After . . . the sewer lines (are) properly cleaned, sections of sewer line . . . shall in turn be isolated from the remainder of the system by means of sewer plugs.

Water shall then be added to the section under test in sufficient quantity to produce a head of not less than 2 feet above the top of the sewer, any appurtenant house services or the ground water table, whichever is greater. When the section under test has been completely filled and all air exhausted, time measurement of the leakage shall be commenced and shall be continued for any period deemed necessary to establish the rate of leakage. Leakage shall be the total amount of water added to maintain the water at the same level as at the start of the test."

Prior to hydrostatic testing, house service laterals are plugged to prevent flooding or overflowing. County of Sonoma Sewerage System Standards require the installation of property line cleanouts in order to facilitate maintenance of the street laterals. The house services are plugged by installing inflatable plugs in the line through the property line cleanouts. In determining exfiltration quantities (or leakage), probable leakage in house service laterals is not included. This leakage is considered to be part of the main line exfiltration.

In areas of steep terrain, it may be necessary to install intermediate tees in the line for hydrostatic test purposes.

A series of hydrostatic tests is run for each line in the "presealing" procedure. It was noted that in most soil types, the buildup of the surrounding water table became evident as succeeding tests showed a drop in the exfiltration rate. In the case of exceedingly porous soils, however, the exfiltration rate remains fairly constant because of the draining effect of the soil.

Air testing is not used in Sonoma County.

Post sealing testing methods also employ the hydrostatic tests and are an indication of the degree of infiltration reduction achieved through line sealing.

FIELD APPLICATION OF EXTERNAL ASPHALTIC SEALING

Determination of Pipe Location

A steel sewer cleaning rod with a cleaning "porcupine" affixed to the forward end of the rod is inserted into the upstream manhole or cleanout and pushed downstream. (See Plate #55) When the cleaning "porcupine" appears at the downstream manhole, the forward progress is halted.

A technician attaches an electronic pipe finder transmitter to the cleaning rod. Specifically, the conductive cable is attached to the cleaning rod. (See Plate #56) Completion of the circuit is indicated by the tone generated in the headset. The loudness of tone fixes the line location.

Having determined the centerline of the pipe, the technician then drives nails through "shiners" for drilling station location. (In unpaved areas, wood stakes are used.) Generally, the first "shiner" station is located at 0 + 03 or 3 feet downstream from the center of the beginning manhole. Stations are located at 15 foot centers thereafter until the downstream manhole is approached, and the final station is located 3 feet upstream from the center of this manhole. Intermediate stations are installed in those areas where underground construction, such as storm drains, may have caused infiltration to occur.

Following the location of the line stationing, cut sheets are developed from the as-built profile drawings of the sewer line; and this information is supplied to the drilling crew for the drilling of applicator holes.

Applicator Installation

Provided with the cut sheets and with measurable depths on the manholes, the drilling crew has a fairly reliable estimate of the depth of the sewer line at the stations; and the drilling is started within one foot of the shiner. (See Plate #57) (Unfortunately, the as-built drawings are sometimes in error; and this occasionally results in the discovery of the line and subsequent holing through by the drill bit.) However, the drilling crew has developed the drilling technique to a point where voids or changes in material can be identified with little chance of error.

Added insurance is provided through the use of a steel probe which is inserted into the drilled hole when a depth of approximately 12 inches over the pipe is reached. The depth of pipe as shown on the cut sheet (less a 6-inch safety margin) is marked on the drill prior to drilling. (See Plate #58)

The Sonoma Valley County Sanitation District sealing crew employs a LeRoi 2 stage, 125 cfm, 100 psi air compressor and a Chicago Pnuematic C-150 wagon drill for drilling the 2¼ inch applicator holes. (See Plate #59) Although drilling time per hole varies with the soil or backfill characteristics, 5 minutes per hole is considered a fair average. Approximately the same time is required to move and set up the drill rig at successive stations.

After the hole is drilled a 6-inch diameter hole approximately 6-inches deep is cut into the area at the top of the drilled hole. (See Plate #60) Loose material is blown from the drilled hole by means of a ½-inch pipe connected to the air supply line. (See Plate #61)

After completion of drilling the field crew installs the applicator pipes. These 3/4-inch pipes are field cut and threaded to fit the depth of drilled hole, allowing for a flexible coupling, vertical pipe plus coupling, and a 4 to 5 inch long 3/4-inch pipe nipple and cap on the bottom end of the applicator pipe. (See Plate #62) The nipple has been previously drilled with ¼-inch holes at approximately one inch O.C. vertically at random spacing. A small amount of pea gravel is filled in around the applicator to minimize plugging of the ¼-inch holes. The applicator is temporarily capped and covered prior to installation of the horizontal piping. (See Plate #63)

At the upper end of applicator pipe an elbow and horizontal length of pipe are fitted between the applicator pipe and a tee which is located just outboard from the valved barrel. (See Plate #64) This horizontal pipe normally crosses from the sewer line to the curb or road side; and, if necessary, the pipe can be installed in a shallow, narrow trench which is covered over with plant mix road patching material. (See Plate #65) The usual method of installation includes strapping the horizontal pipes to the road surface utilizing "plumber's tape" and concrete nails. (See Plate #66) Normally, the horizontal length of pipe is recovered for re-use. The applicator may be reclaimed but the labor involved scarcely justifies this recovery, particularly since the applicator pipe is surrounded with tamped backfill material, including approximately 6-inches of plant mix at the road surface.

A short riser pipe is connected to the vertical leg of the tee. (See Plate #67) Between the riser and the supply tank or drum is a union and a 3/4-inch valve which is used to control the flow of asphalt into the applicator.

Generally, the barrels are placed at regular 15-foot spacing. However, where space limitation is a problem the barrel location is revised and "stacking" is provided as requires. (See Plates #68 and #69)

Sealant Application

The primary sealant, SC-70, is delivered to the County maintenance district yard at 150° to 200° F. in a heated tank delivery truck and is loaded into a 400-gallon Grace Co. asphalt trailer at approximately 135° F. (See Plate #70) However, if the delivery truck tank temperature is below 150° F. the tank truck operator is requested to reheat the material.

The barrel is filled with hot asphalt, and the valve is opened to allow gravity flow into the applicator piping, until the piping is full; then the valve to barrel is closed.

The discharge hose from the oil pot is connected to the stand pipe, and the SC-70 is discharged into the stand pipe at approximately 40 psi. (See Plate #71) When a sudden drop in gage pressure is evident after the fast-acting shut-off valve on the oil pot is closed — it is assumed that the soil or backfill around sewer line has been "broken". This indicates that the backfill between the applicator and the sewer line has "cracked" sufficiently to allow penetration and distribution of the asphaltic material. Occasionally the pressure must be increased above 40 psi in order to break the soil.

There are three possible situations which can preclude breaking at any pressure:

1) No applicator installed on pipe (only a pipe cap).

2) No holes drilled in applicator nipple.

3) Holes in applicator sealed shut by soil (clay or adobe).

After "breaking", the discharge hose is disconnected, the stand pipe is capped, and the valve to the barrel is opened.

If, on examination of the flow through the standpipe, the SC-70 is not flowing into the applicator, the "breaking" process with hot SC-70 is repeated.

Should this application still not produce a flow, the barrel valve is shut off and pressure is applied at the stand pipe by use of a bicycle tire pump through a check valve adapted to a 3/4-inch pipe cap. If this is not successful, the stand pipe is capped; and the bicycle tire pump is used to apply pressure to the barrel.

If the SC-70 still doesn't move, the applicator location is "abandoned" and the contents of the barrel are moved upstream to the next applicator location. It is hoped that the total content of both barrels of SC-70 will then move downstream from this location and serve the purpose. (An average of one barrel in five will create a problem situation.)

Application of the SC-70 is considered complete when one barrel (approximately 45 gallons) has been injected at each location. With applicator spacings of 15 feet, this represents approximately 3 gallons per foot of line. Should a barrel stop flowing before becoming empty, the remaining contents are poured into the next upstream barrel.

After the first 7 barrels (approximately 400 gallons) are "on-stream", the downstream manhole is opened for inspection. With each 400 gallons load, the manhole is re-opened for inspection. Generally, the SC-70 will show up initially as small buttons which subsequently grow into ribbons of half-dollar sized "blobs". No attempt is made to trap or remove SC-70 from the sewer line.

During the SC-70 application, the barrel valves are closed only if necessary. Usually the barrel is allowed to flow until the full 45 gallon amount is depleted through the applicator. However, an occasional "leak" develops along the applicator pipe, causing SC-70 to break through to the road surface and form a pool of asphalt surrounding the applicator location. Application is discontinued until the road surface material surrounding the applicator is retamped until tight.

The travel of the SC-70, normally within the trench walls, is through paths which have been formed by leaking sewage or through the interstices of the backfill. In either case, the SC-70 coats the soil particles with which it comes into contact; and this action, in turn, provides pathways for the secondary sealant, namely the RS-1.

It had been believed for some time that the SC-70 did not seal the soil surrounding the sewer line. Later observation has shown that after a number of years setting, the SC-70 also seals the soil surrounding the sewer.

After allowing an average of one week for saturation of the SC-70 the field crew fills the barrels with RS-1, and the valves are opened. Each applicator is checked for air locks. In case of an air lock or stoppage due to an unintentional siphon, the bicycle tire pump is used to start the flow.

At the start of the barrel filling operation, a water tank truck is located at the flushing inlet or the upstream manhole; and a sand trap is installed in the downstream manhole. The RS-1 shows up in the flow line in the form of lumps which are formed by the combination of the RS-1 and the salts in the sewage. Flushing the line moves the lumps downstream where they are manually removed from the sand trap and placed in 5 gallon buckets. (See Plate #72) This RS-1 is discarded.

The RS-1 application continues until refusal, with the barrels being refilled as required. Normally, the barrel valves are shut off each night, flow of RS-1 being continued only during normal day shift operations.

An average of one barrel in ten will not stop draining RS-1, and this necessitates use of the "salting" operation. "Salting" is employed to develop a dam in those cases where an inordinate amount of RS-1 is being used by a given applicator. Large fissures in the soil cause this type of flow, as do large breaks in the line.

Salting equipment includes: a 200-gallon capacity air pressure paint pot equipped with hoses for air and salt water; 50-lb. bags of coarse stock salt; and 200-gallons of dyed water.

Salting procedure is initiated by opening the valve on the RS-1 barrel and allowing flow to continue for 15 minutes. The valve is then closed, and the air hose is connected to the applicator line which is "blown out" to void any residual RS-1. The salt water hose is connected to the stand pipe and a 15 psi pressure is applied from 5 to 10 minutes. Pressures in excess of 15 psi tend to cause leakage around the applicator pipe at the road surface.

Following the above, the salt water line is disconnected and the applicator line is again blown out. The RS-1 application is started and closely watched in order to determine if the salting has been successful. (In some stubborn cases the salting operation is repeated six times before an adequate "dam" is created)

In case the previous salting approach is unsuccessful, the next approach is to introduce 50-lbs. of salt into the upstream manhole together with approximately 400-gallons of water. The flow is deliberately impeded through the use of a rubber ball or part of the salt sack. The obstruction is placed in the channel prior to dumping the salt and water, considerably reducing the velocity and allowing the salt water to "break" the RS-1.

The use of a pressure type ball was discontinued when it was discovered that this ball tended to scour the congealed RS-1 from the interior and, in effect, break open the sealed areas.

Finally, if none of the above methods are effective, excavation remains as the only total solution to the "leaker" problem.

At the conclusion of the RS-1 application, the barrels are removed; and the applicator pipes are removed. Removal of the vertical section of applicator pipe below the flexible coupling has been discontinued, as previously mentioned, because of the excessive cost of labor involved in "pulling" the pipe.

STUDY AREAS

FORESTVILLE COUNTY SANITATION DISTRICT

This District encompasses approximately 50 acres, and the collection system within this area consists of 6-inch, 8-inch, and 10-inch street lateral lines. (See page SM - 8)

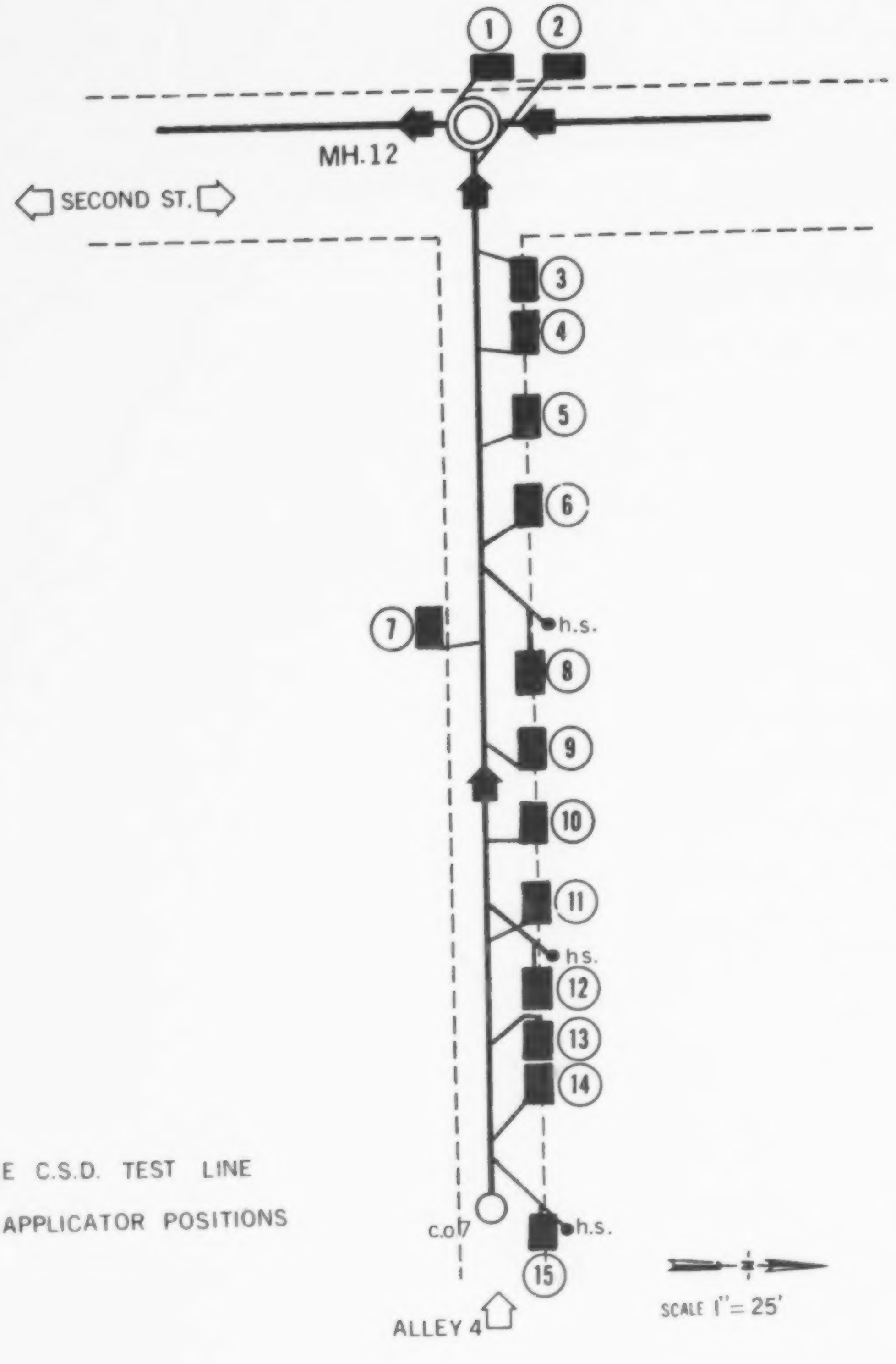
The soil can be described as light brown silty sand (SM).

Soil sampling was by means of a hand auger with field classification by 2 soils engineers. (See Plate #73)

Selection of the 160-foot test line was based on the following parameters: use of 6-inch vitrified clay line with mortar joints, unpaved road surface (See Plate #74), use of native material for pipe bedding and backfill, and excessive exfiltration.

Exfiltration testing was conducted by plugging the downstream manhole and filling the line through the cleanout at the upstream end. The difference in elevation in manhole and cleanout inverts is 4.6 feet. Filling the cleanout adds approximately 2.5 feet of head. Results of four tests show exfiltration averaged greater than 87,000 gallons per day, per inch diameter, per mile. (See pages HT - 1 & 2) Maximum allowable in new construction is 250 gallons per day, per inch diameter, per mile.

Following usual procedure, sealant applicators were installed on 15-foot centers except that one additional applicator was installed at each of the three house services on this line. Also, one applicator was installed downstream from manhole #12. (See Figure 1)



FORESTVILLE C.S.D. TEST LINE
SHOWING APPLICATOR POSITIONS

FIGURE 1

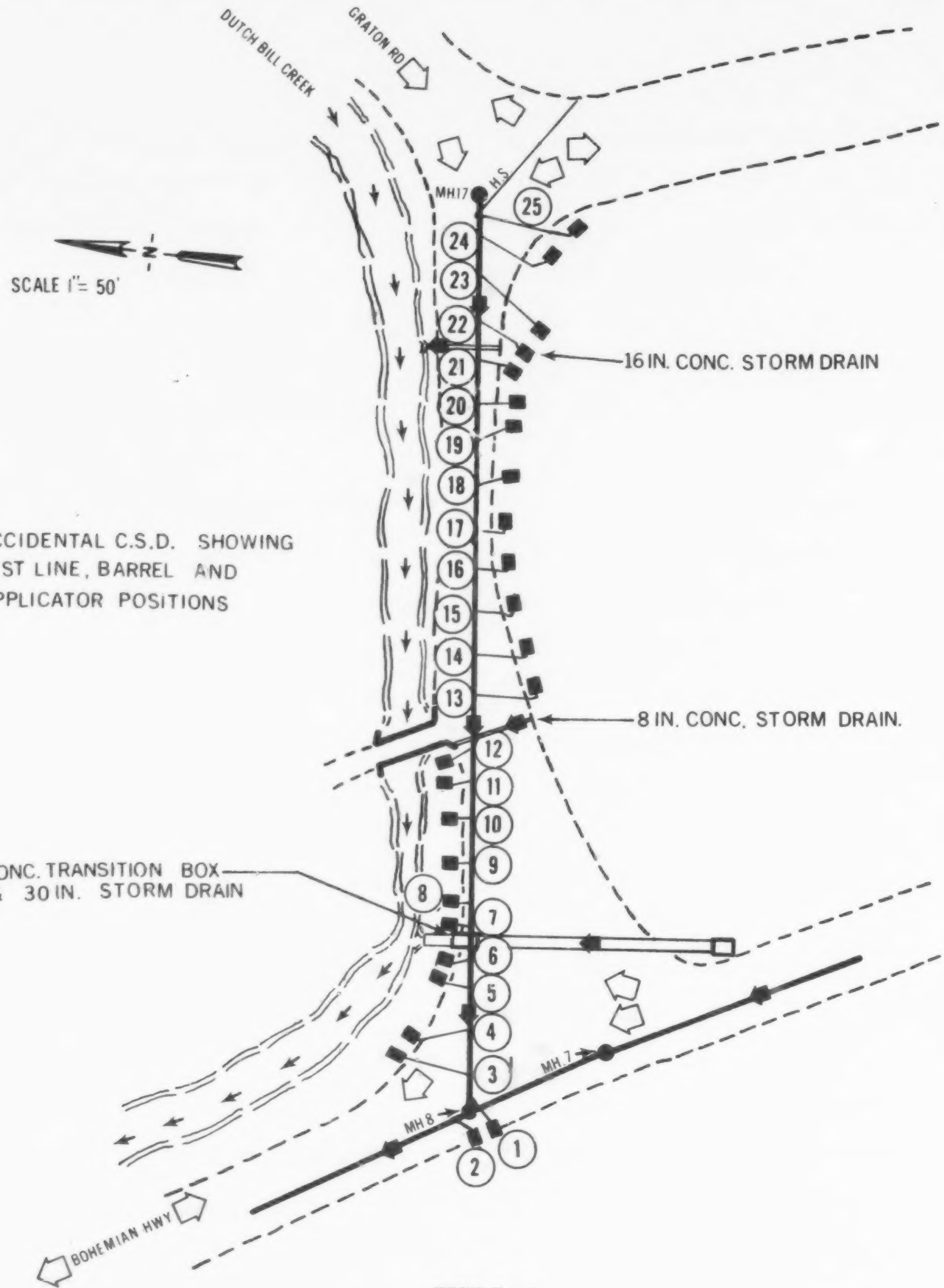
A weep pipe and valve was fitted into a drilled hole in manhole #12 in order to determine the buildup of asphaltic material outside the manhole. Visual inspection of the asphalt level in the vertical leg of the weep pipe indicates the level of asphaltic buildup. (See Plate #75)

Initial applications of the SC-70 was in accordance with usual field application procedure. The SC-70 application was started on May 9, 1966, and was considered completed on June 14, 1966. A total of 925 gallons of SC-70 was used.

Application of the RS-1 was started on June 14, 1966, and completed on August 12, 1966. A total of 1010 gallons of RS-1 was used. Waste RS-1 collected in the downstream manhole amounted to 225 gallons.

The RS-1 application was also a "normal" application. "Salting" was used on applicators Nos. 5, 9 and 12. Usage varied from 45 gallons in the slowest running barrel up to 295 gallons in the fastest. The three "salted" applicators had used 295, 180, and 175 gallons, respectively.

Exfiltration tests performed after application of the RS-1 material averaged slightly more than 4200 gallons per day, per inch diameter, per mile. The net reduction of exfiltration was calculated as approximately 95%.



OCCIDENTAL C.S.D. SHOWING TEST LINE, BARREL AND APPLICATOR POSITIONS

FIGURE 2

OCCIDENTAL COUNTY SANITATION DISTRICT

The area included in this District is approximately 37 acres, and the 5800 lineal feet of collection system is made up of 6-inch concrete street lateral lines. (See page SM - 9)

The soil was sampled by means of a hand auger and was field classified as dark brown clay (CL). Shale is also predominate in the surrounding area.

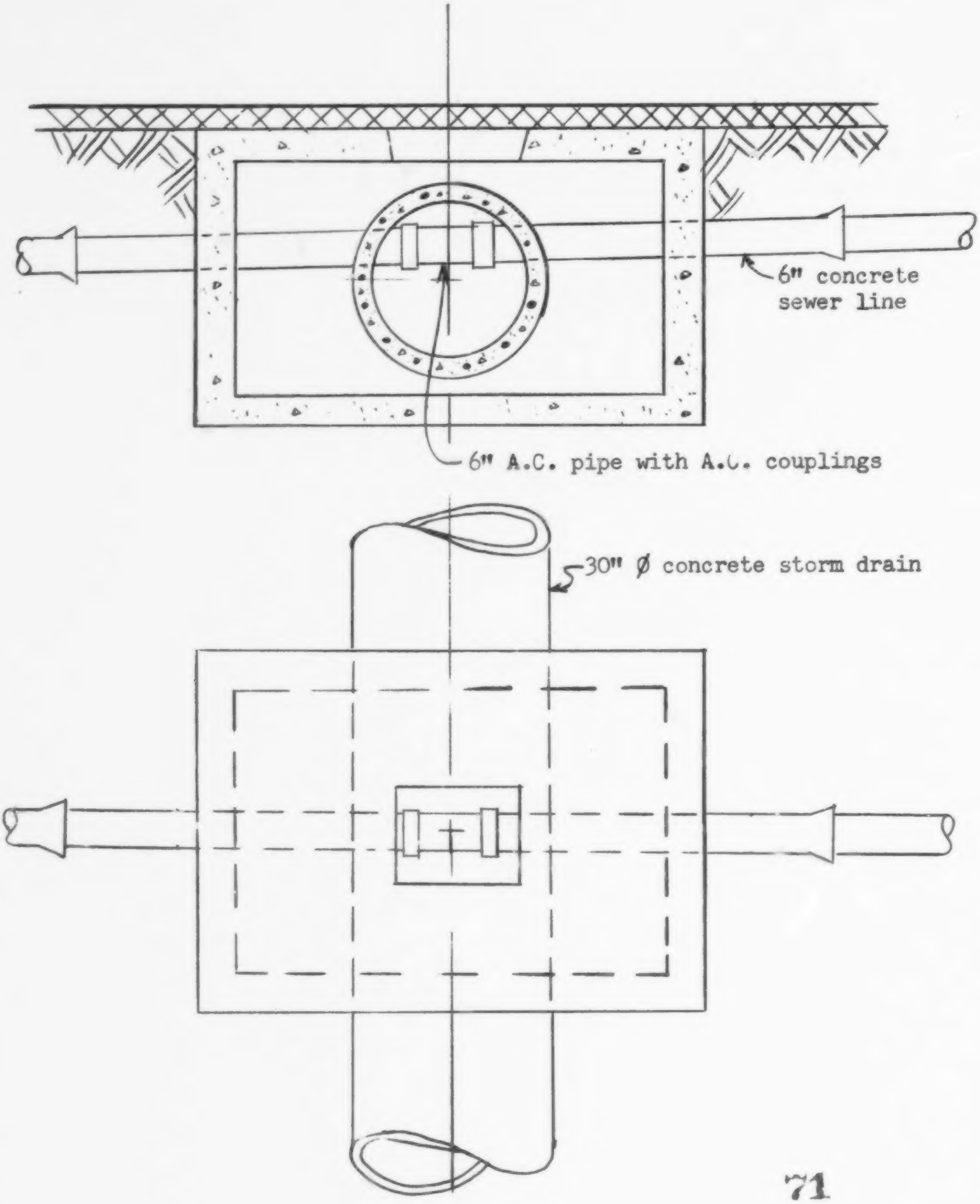
Selection of this 330-foot test line was based on the following parameters: use of 6-inch concrete pipe with mortar joints, oil and rock chip (armor coat) pavement (See Plate #76), use of native material for backfill, excessive infiltration, and only one house service. In addition the presence of three storm drains crossing the street lateral location, indicated potential infiltration problem areas. The extent of one storm drain problem will be discussed later.

Exfiltration testing was conducted by plugging the downstream manhole and filling the line through the upstream manhole. Difference in head between the inverts is 5.2 feet. Results of six tests showed average exfiltration of approximately 152,000 gallons per day, per inch diameter, per mile. (See page HT - 3)

A total of 25 applicators were installed, generally on 15 foot centers. In the areas where storm drains crossed the sewer line, applicators were installed straddling the drains. One applicator was installed downstream from manhole #8. (See Figure 2) This manhole was also fitted with weep pipe installation.

The SC-70 application was started on May 9, 1966, with the filling of Barrels #1 through #7. (See Figure 2). Barrels #7 through #25 were filled on May 10, 1966. Road surface leaks at applicators #3, 24 and 25 were evident, and SC-70 showed up in the flow channel of manhole #8. On May 12 and 13, leaks were sealed at applicators #12, 14, 16, 22, 23 and 25. On May 16, a substantial amount of SC-70 appeared at the downstream end of the 30" concrete storm drains. (See Plate #77)

A visual inspection of the inside of the 30" drain showed the 6" sewer line crossing the storm drain through a 3½ foot x 3½ foot x 7 foot concrete transition box. (See sketch below)



No record or "as built" in the Department records indicates the existence of this box. The sewer line in the box was a 6-inch asbestos-cement section of pipe attached to the concrete pipe by means of couplings in which the gaskets had been omitted.

Because initial exfiltration tests had been conducted prior to the discovery of the drain crossing problem, it was decided to continue the sealing experiment without repairing the leaking couplings. A concrete hatch cover was found buried in the roadway, and access to the box as well as inspection at the couplings was possible.

Application of the SC-70 continued, and on May 23 all barrels were subjected to pressure treatment. The final SC-70 was applied on June 14, and this part of the treatment was considered complete. A total of 1400 gallons of SC-70 was used.

On June 15 barrels #2 through #14 were filled with RS-1. Within 1½ hours after the initial filling, RS-1 was visible in the concrete transition box as well as in the flow channel in manhole #8.

During the next 6 weeks application of the RS-1 was carefully controlled. Flushing of the line caused the leaking couplings on the transition box to break open with each flushing application. (See Plate #78)

In mid-August the decision was made to fill the box with 3/8" minus aggregate (backfill material) and treat the line as part of a normally buried line. The time element was daily becoming more important inasmuch as the early autumn rains were rapidly approaching; and blocking of the storm drain transition box would, of course, cause upstream flooding. Therefore, only the application of 175 gallons of RS-1 in the box was accomplished; the SC application was not used.

On August 23, thirteen barrels were given the "salting" treatment, and the RS-1 application was considered complete. The total RS-1 used was 1150 gallons. Waste RS-1 collected in the downstream manhole totalled 120 gallons.

On September 27, an exfiltration test was attempted. However, excessive leaking in the concrete transition box ruled out any possibility of a representative test.

A final attempt to externally seal this section of the line was made on October 6; and in this attempt the backfill material in the box was replaced with ocean beach sand, salt, and RS-1 mixed together while being placed. Hydrostatic testing on October 10 again caused excessive leakage and the decision was made to replace the faulty section of the line with cement-lined cast iron pipe.

Final exfiltration tests on October 20 showed an average rate of 46,000 gallons per day, per inch diameter, per mile. (See page HT - 4). This represented a net reduction in exfiltration of approximately 95%.

BODEGA BAY

At present, there is no County Sanitation District at Bodega Bay. Therefore, it was decided to construct a short test line in a tidal flat in this area in order to determine the effect of salt water intrusion as well as the reactions of salt water on the sealing process in general. (See Plate #81)

Prior to construction, several sample sections of line were assembled and tested at the El Verano Corporation Yard in order to develop a jointing method which would reproduce leaking conditions. (See Plate #83)

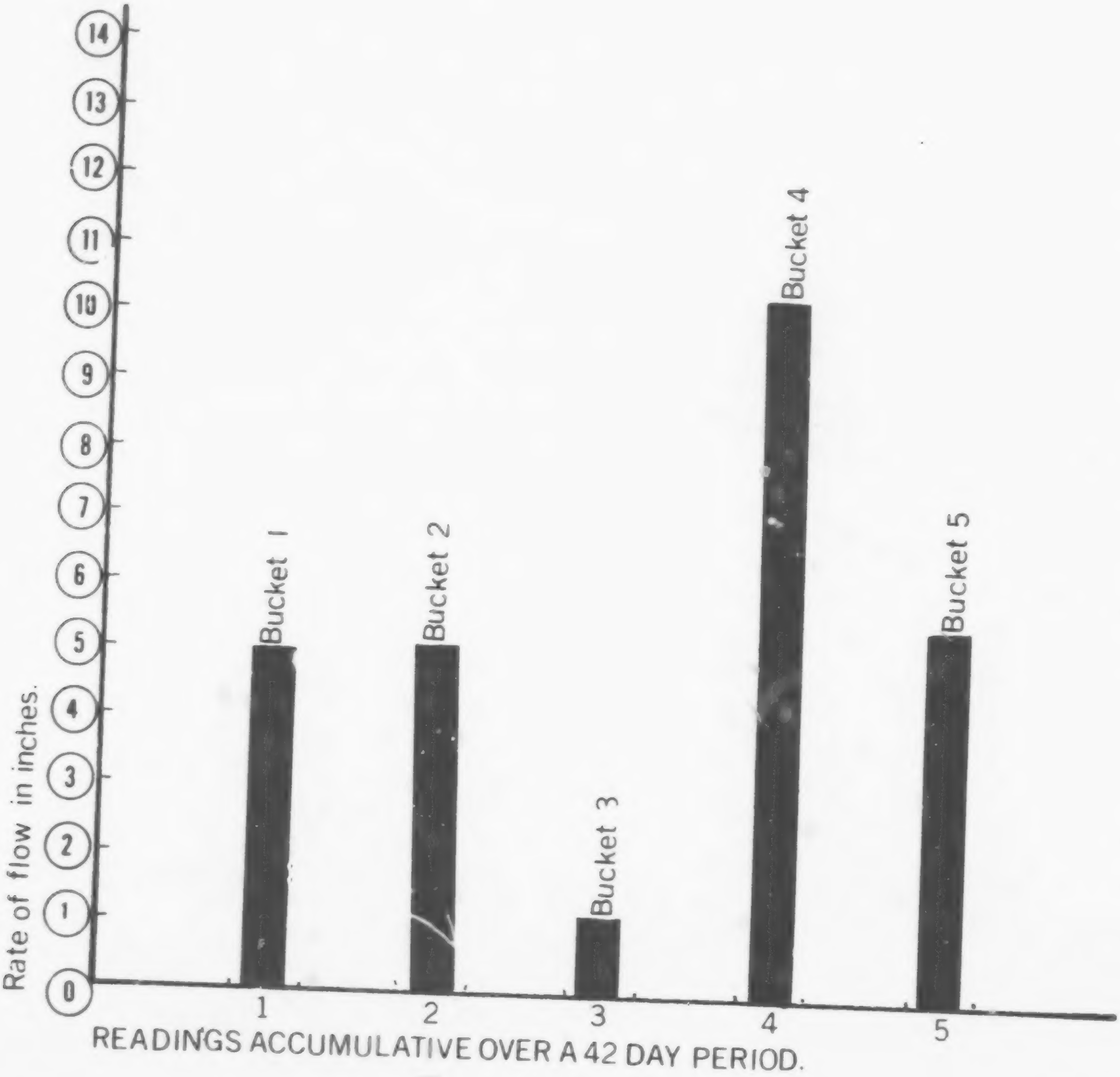
After training in poor joint construction the District crew installed the 8-inch vitrified clay line at Bodega Bay. (See Plates #79 and #80) While the line was constructed at a constant grade (S=0.00625), no attempt was made to keep horizontal alignment accurate.

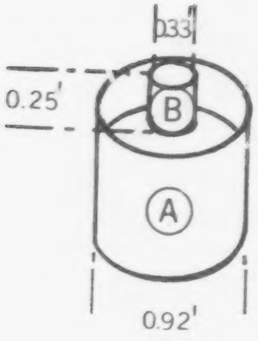
Trenching for the line was carried to several inches below normal trench bottom, which is usually three inches under the couplings. This was done in order to facilitate the installation of two underdrains in the bedding. A 3/8-inch minus aggregate (waste pea gravel) was used for pipe bedding.

The underdrains terminated in a 55 gallon drum sump as did the downstream end of the 8-inch V.C. pipe. Each underdrain consisted of 4 to 5 foot lengths of 1½-inch black steel pipe connected by means of 1½-inch tees.

The purpose of the underdrains was to keep the bedding material free of salt water during the asphalt application, and in this manner preclude "breaking" of the asphalt at some level above the leaking joints.

Also installed in the discharge sump was an electrically operated sump pump and a drum type recorder which was intended to show tidal action and pumping cycles. However, several inundations under extremely high tides rendered





Bucket No.	Ⓐ	Ⓑ
1	Dry Sand	SC–70
2	Combined Damp Sand & Aggregate,	SC–70
3	Saturated Sand,	RS–1
4	Saturated Sand.	SC–70
5	Damp Sand,	SC–70

Note: Saltwater used for saturation

FIGURE 3

Reproduced from best available copy.

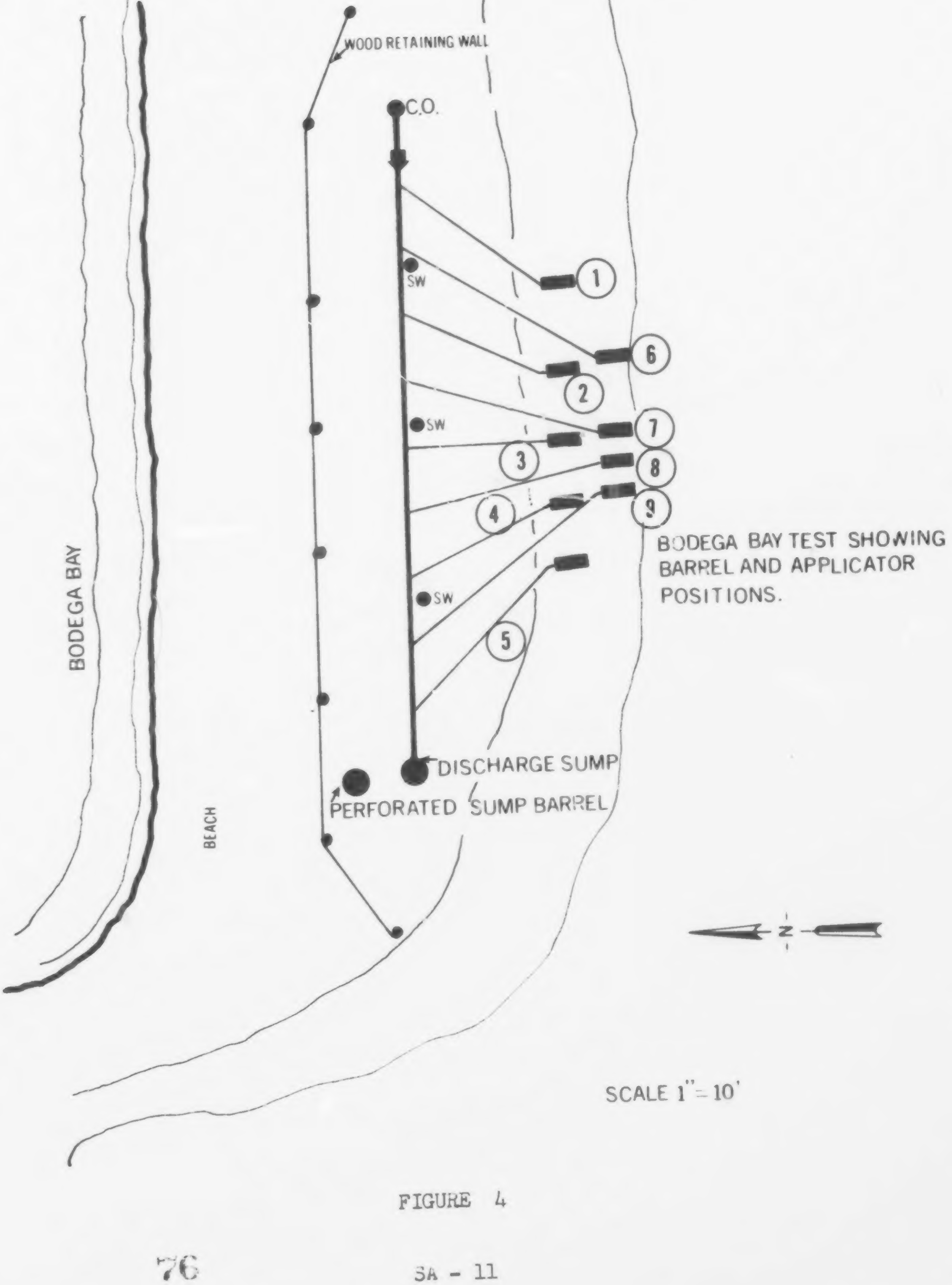

WOOD RETAINING WALL
C.O.
SW
SW
SW
1
6
2
7
3
8
4
9
5
BODEGA BAY TEST SHOWING BARREL AND APPLICATOR POSITIONS.
BODEGA BAY
BEACH
DISCHARGE SUMP
PERFORATED SUMP BARREL
N
SCALE 1"=10'

FIGURE 4

this part of the test somewhat inconclusive.

After installation of the 8-inch vitrified clay pipe, three sight wells were installed to facilitate viewing tidal intrusion over the pipe. The maximum elevation of the pipe was set at an elevation at which a 6.3 (See Plate #82) foot tide would inundate the pipe at the upstream or cleanout end of the line.

The approach to sealing this line was to be as follows:

1. Apply the SC-70 during a period in which tidal intrusion would be kept minimal by draining the bedding;
2. Apply the RS-1 under similar conditions· and
3. Plug the underdrains and allow the tidal water to rise in the trench, thereby "breaking" the RS-1.

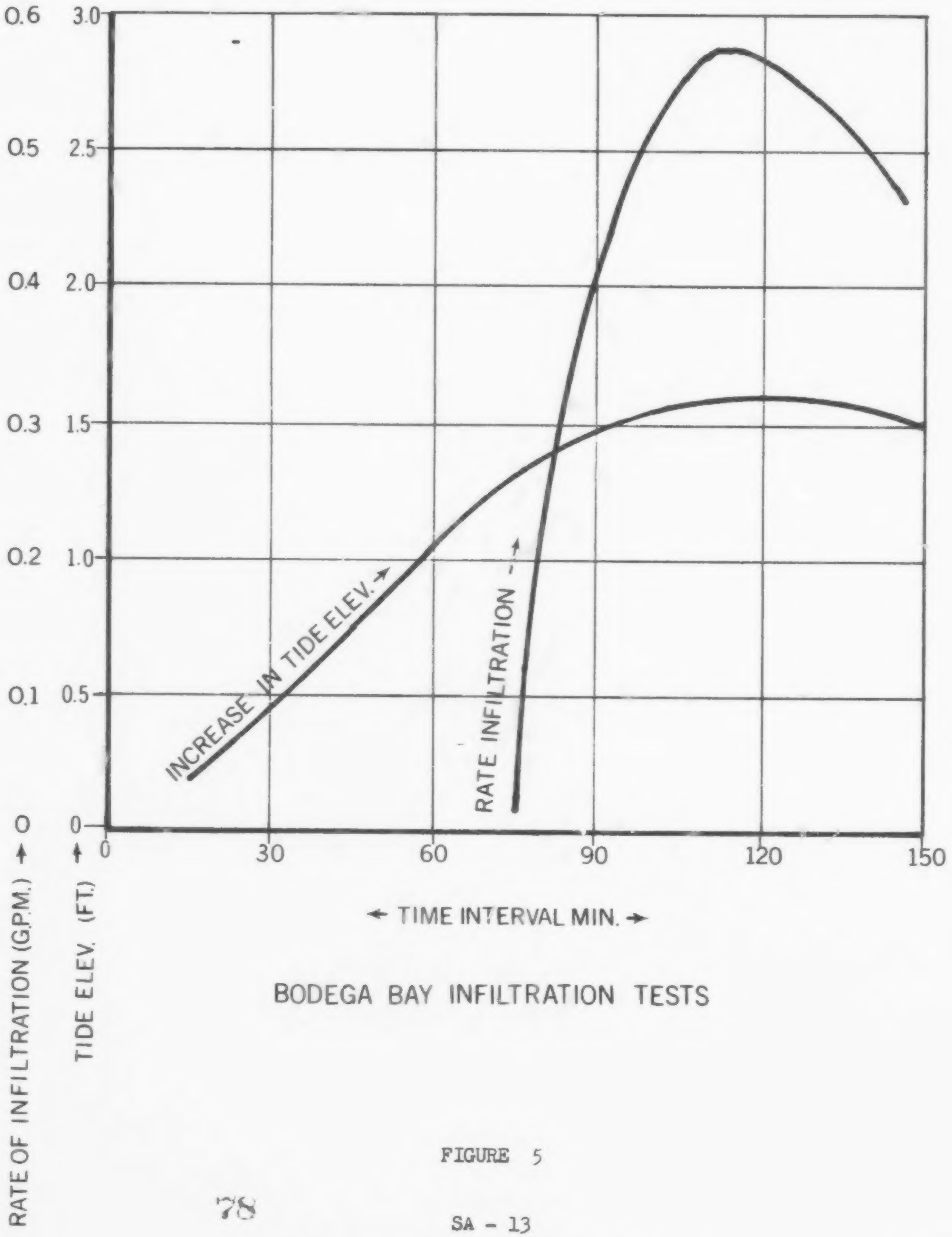
Initial hydrostatic tests were conducted by filling the line through the 6" cleanout. Exfiltration was calculated at approximately 344,800 gallons per day, per inch diameter, per mile of pipe.

Nine applicators and barrels were installed. (See Figure 4)

At the suggestion of the engineering consultants, Engineering-Science, Inc., a series of five tests were run utilizing SC-70 and RS-1 in several types of backfill media. (See Plate #85) The results of these tests are shown on Figure 3. Flow of the SC-70 through the damp beach sand indicated the improbability of setting the SC-70 under salt water intrusion. It was decided to discontinue draining the bedding material, plug the under drains, and initiate the SC-70 application after an actual infiltration test was performed.

September 13 was selected as the day for the infiltration test because of the 6.3 foot high tide on that date. (See Plate #84)

A calibrated (one gallon) container was used to determine infiltration as



BODEGA BAY INFILTRATION TESTS

FIGURE 5

the tide level increased. By measuring the increase in water level in the perforated sump the increase in tide elevation could be determined. Concurrently, the time interval required to collect each gallon of infiltration was measured. Both of the above values were plotted as shown on Figure 5.

At maximum tidal effect, the rate of infiltration was in excess of 0.5 gallons per minute. By flooding the test area, infiltration of approximately three times the tidal infiltration was developed. Photographs showed the leakage to be fairly uniform in all joints. No leakage was evident in the upper portions of joints, the infiltration appearing as seepage at the pipe invert.

On September 23, 1966, the applicator barrels were filled with SC-70 in the normal manner. Within one day, approximately 20 gallons of SC-70 had entered the line and collected in the discharge sump. After five days of SC-70 application, this part of the test was considered complete. A total of approximately 30 gallons of SC-70 had drained into the discharge sump. Total gallons of SC-70 used was 405.

Application of RS-1 was started on September 28, 1966. The tendency for the RS-1 to leak at the surface around several applicators was apparent; but this did not constitute a serious problem because the barrel valves were throttled to control flow.

As of October 7, the RS-1 application was considered complete. A total of 595 gallons was used. Waste RS-1 was 35 gallons.

An exfiltration test was conducted on October 10, in which the downstream end of the line was plugged, and the line was filled through the upstream cleanout. Total loss through exfiltration was calculated at 250 gallons per minute, per inch diameter, per mile of pipe. This is also the allowable exfiltration rate specified by the County Sewer Construction Standards for new sewer construction. This represents a 99.9 per cent reduction in exfiltration.

On October 14 another 6.3 foot tide occurred, and this presented an opportunity to compare "before and after" exfiltration rates. The increase in tide elevation was measured in the same manner as before. Infiltration during this tide, however, was negligible. The amount collected could not be measured because the total infiltration scarcely moistened the bottom of the gallon can.

SONOMA VALLEY COUNTY SANITATION DISTRICT

The total area in the three Local Improvement Districts is approximately 4200 acres. The collection system includes approximately 51 miles of 6-inch through 24-inch lines, and the pipe materials used included cast iron, concrete, vitrified clay and asbestos cement. (See pages SM - 1 to 7)

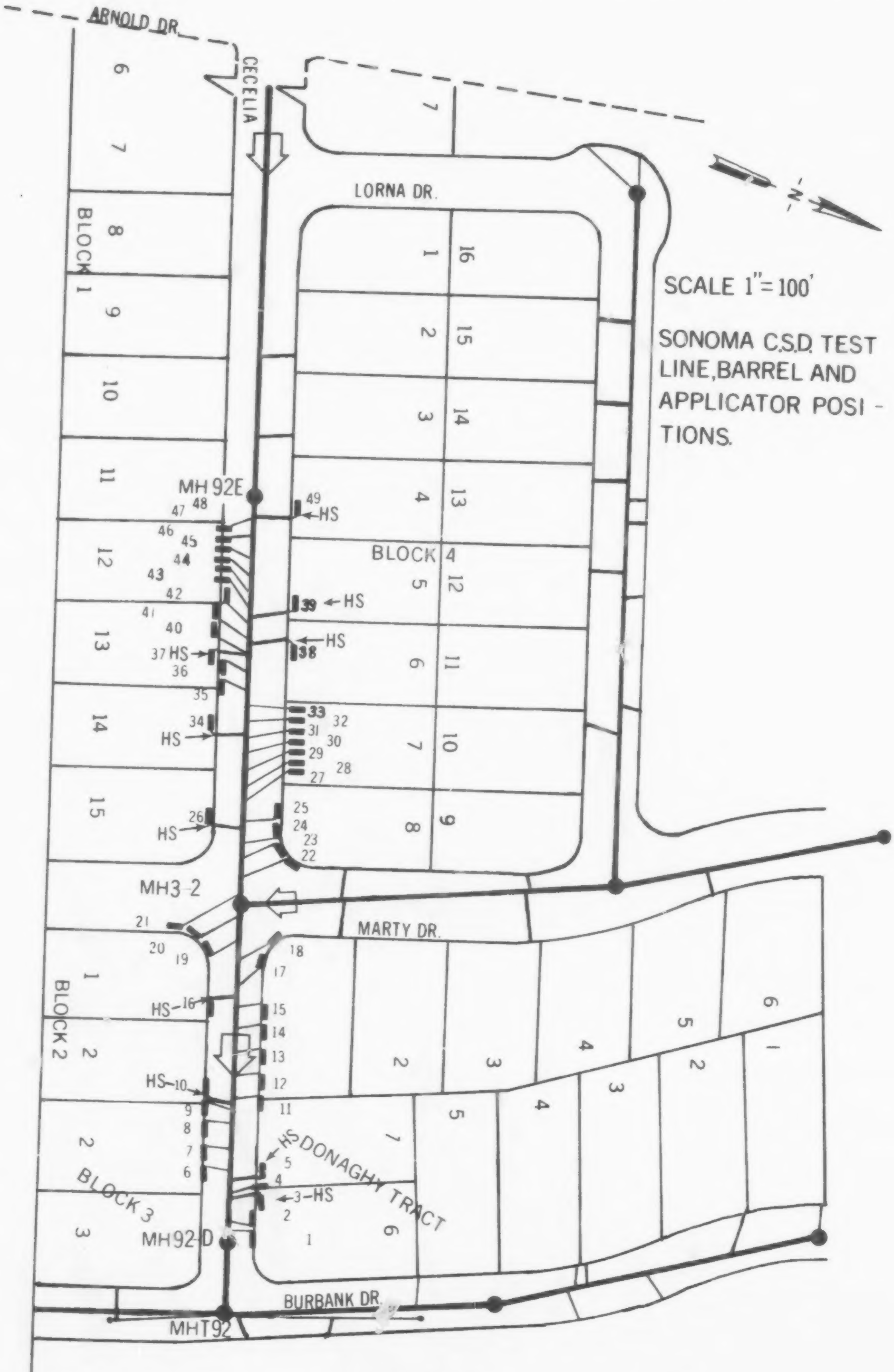
A soils engineer classified the soil as brown sandy clay (CL). This soil is locally referred to as "adobe".

The test line selected in L.I.D. District #3 is 546 linear feet of 6-inch vitrified clay line with hot-poured joints. Additional reasons for this selection are: paved streets (asphalt) with curb and gutter as well as the connection of a number of house services to the sewer line and use of native material for bedding and backfill. (See Plates #86 and #87).

Exfiltration tests were conducted by first isolating 247 feet of line between manholes number 92-D and 3-2. Man hole 92-D was plugged. The house services were plugged by installing inflatable rubber plugs at the property line cleanout. Difference in elevation between inverts in the above manholes is 6.4 feet. Results of five tests showed an average exfiltration rate of approximately 219,000 gallons per day, per inch diameter, per mile of pipe.

The remaining 299 feet of line, between manholes 3-2 and 92-E, was similarly isolated and plugged. Difference in invert elevation in these manholes is 2.4 feet. Five tests were performed, and the average rate of exfiltration was 51,000 gallons per day, per inch diameter, per mile of pipe.

Installation of the sealant applicators was on 15-foot centers, and no intermediate applicator spacing was used for the house service laterals. A total of 49 asphalt barrels were placed in the gutter on wood platforms. (See Figure 6)



SCALE 1"=100'

SONOMA C.S.D. TEST LINE, BARREL AND APPLICATOR POSITIONS.

FIGURE 6

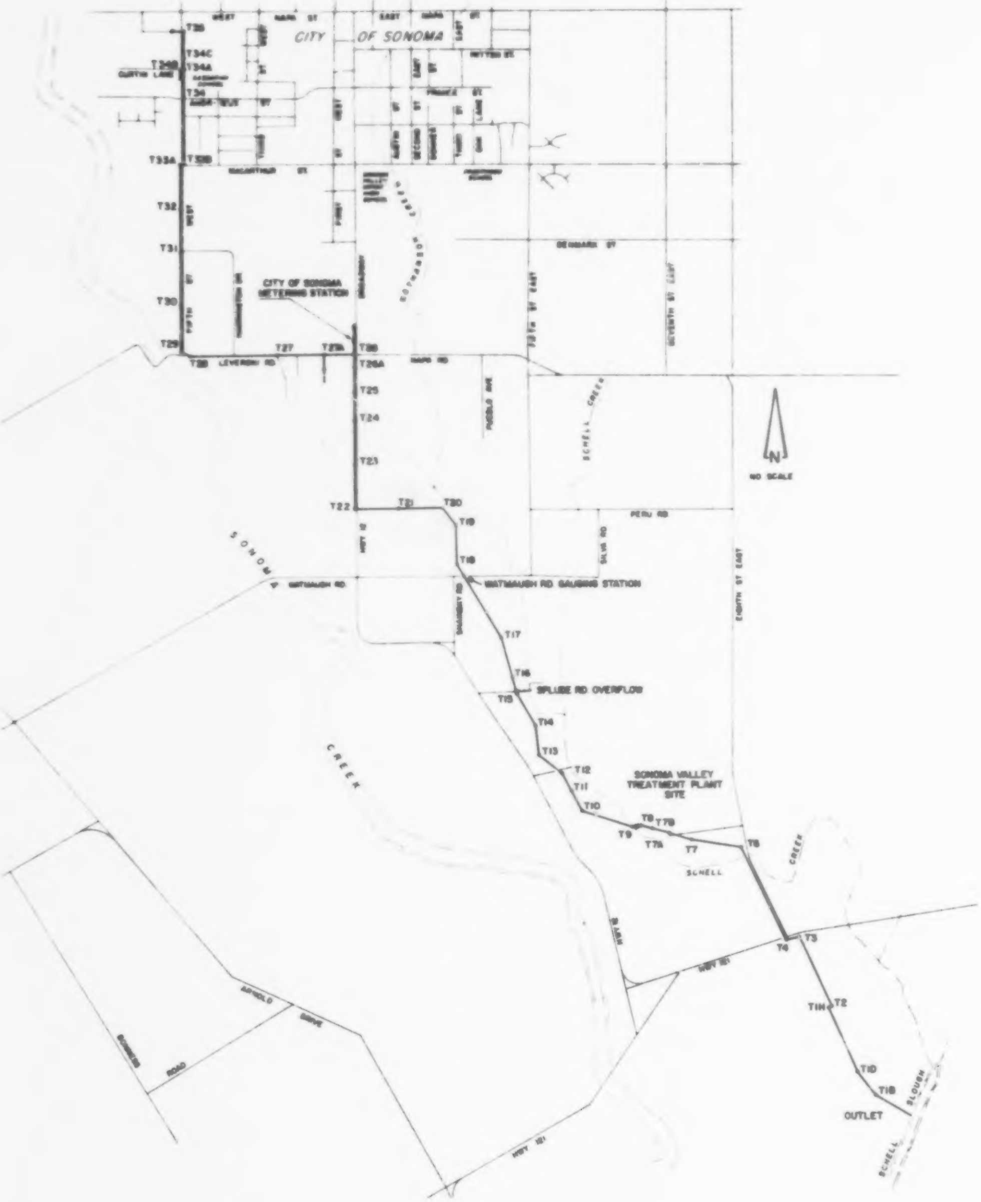
Horizontal piping was buried beneath the pavement surface in the usual shallow trench which was backfilled with cold patch material. Each manhole was fitted with a weep pipe.

Initial application of the SC-70 was started on July 20, 1966. Although the SC-70 was still being applied as late as October 1 in two barrels, the RS-1 application was started in the downstream barrels on August 29, 1966. The SC-70 flow in the downstream barrels seems to have been faster than usual, but no substantial increase was evident in the downstream manhole channel. Similarly, flow of RS-1 was faster than usual in the same area. However, large accumulations of RS-1 in the form of clods were not evident. A total of approximately 2200 gallons was used.

Flow of both asphaltic materials in the upstream section of the test line was slow. As of this writing (early November) the RS-1 application was still in process. Up until this time a total of approximately 5000 gallons of RS-1 was used. Waste RS-1 totalled 75 gallons. It would appear, from the prodigious amount of RS-1 used, that the presence of an old stream bed below the lower reaches of the test line caused some of the sealant to be drained off. This is corroborated by the lack of visible evidence of sealant in the manhole channels.

Although the RS-1 application is not considered complete, and localized dye testing and salting will be required in order to block those areas in which loss of sealant is excessive, exfiltration testing was performed. This was done to determine the degree of sealing which had been achieved.

The results of five tests in the section between manholes 92-D and 3-2 showed an average exfiltration rate of 52,000 gallons per day, per inch diameter, per mile of pipe. This represents a net reduction of 76 percent. Similarly, five tests performed on the section between manholes 3-2 and 92-E show an average exfiltration rate of 7200 gallons per day, per inch diameter, per mile of pipe, or a reduction of 86 per cent.

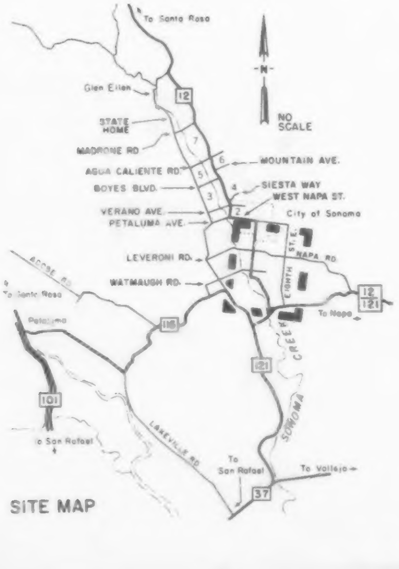


LEGEND

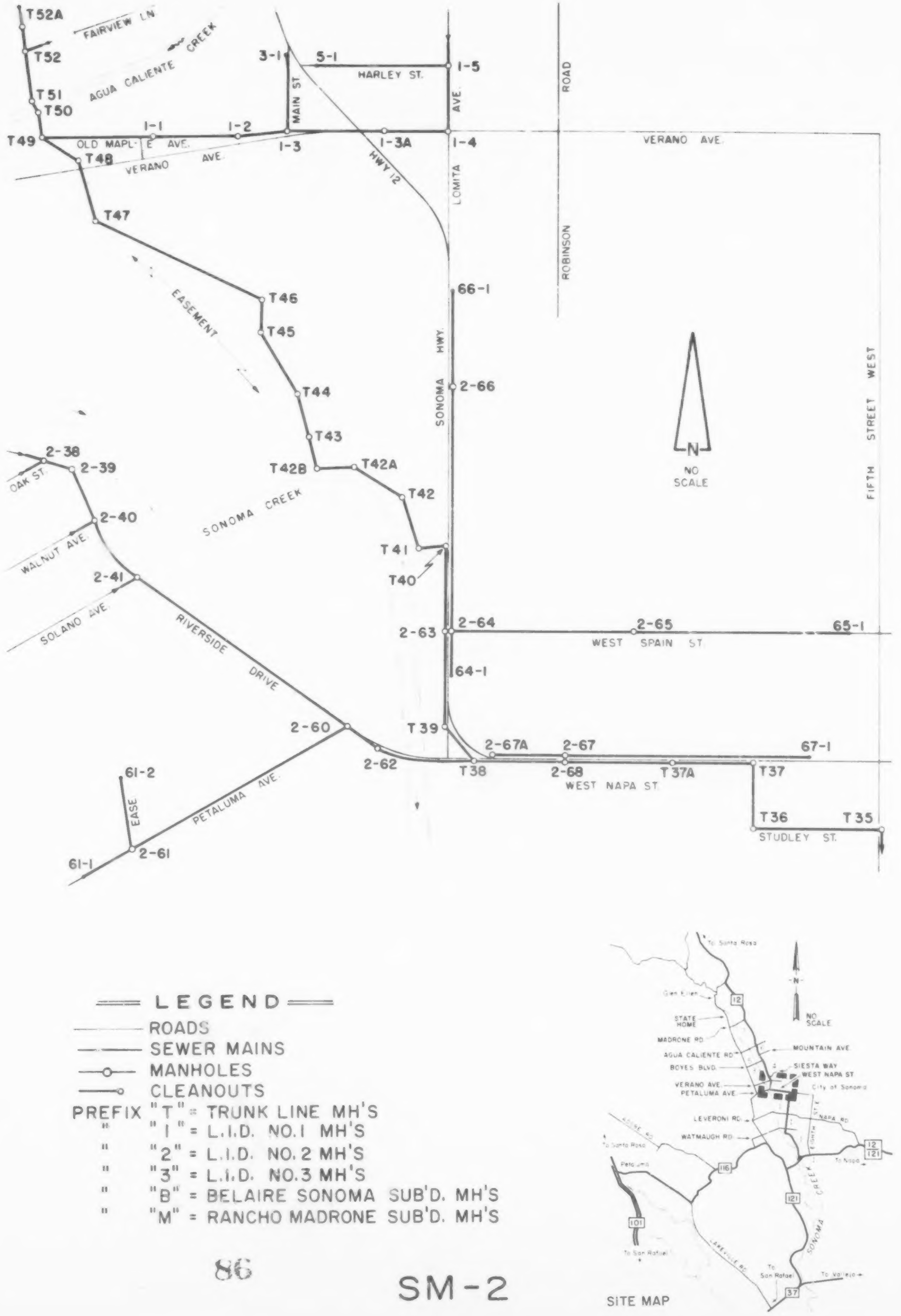
- ROADS
- SEWER MAINS
- MANHOLES
- CLEANOUTS

PREFIX "T" = TRUNK LINE MH'S
" "1" = L.I.D. NO.1 MH'S
" "2" = L.I.D. NO.2 MH'S
" "3" = L.I.D. NO.3 MH'S
" "B" = BELAIRE SONOMA SUB'D. MH'S
" "M" = RANCHO MADRONE SUB'D. MH'S

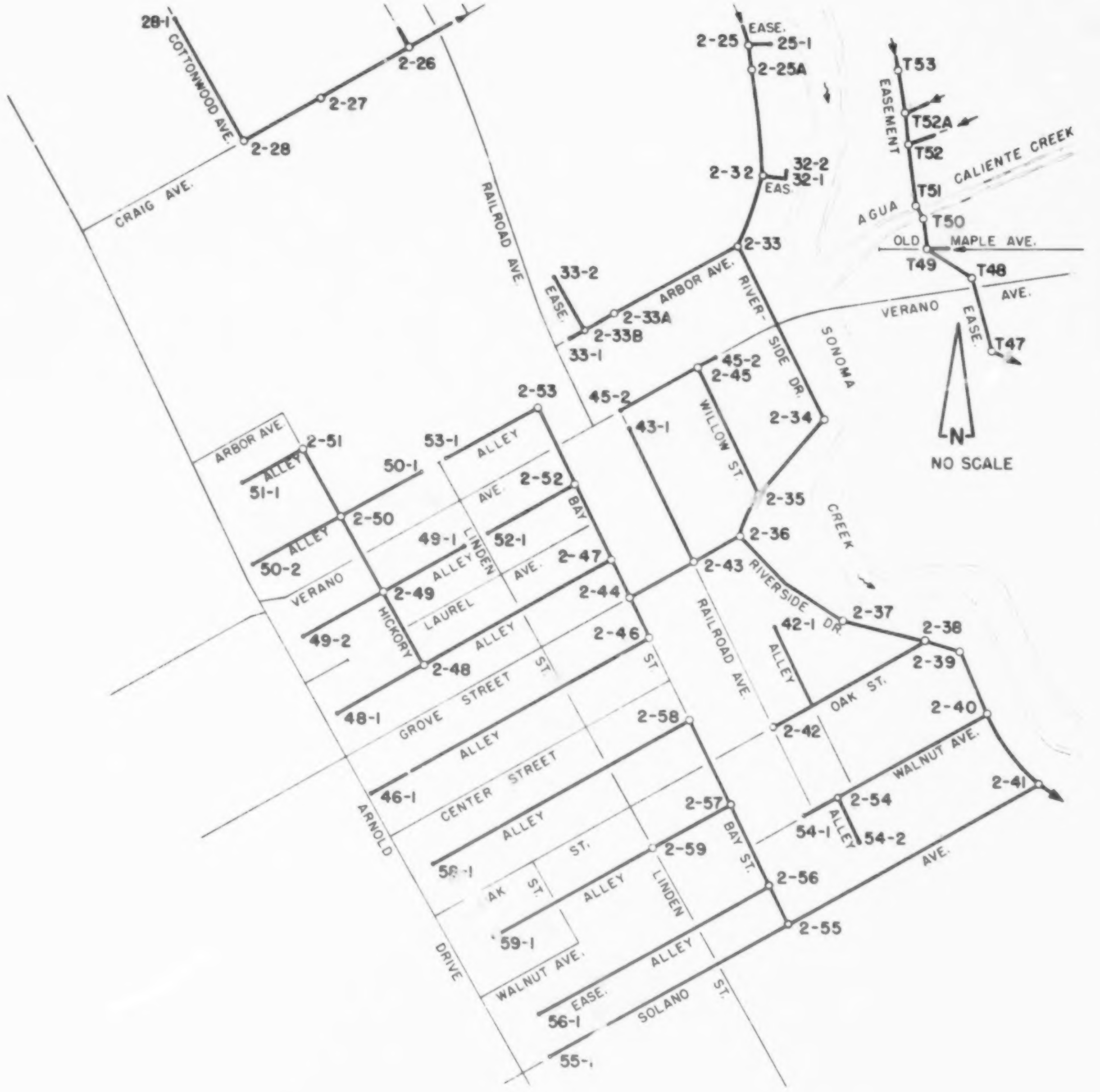
SM-1



SITE MAP


T52A
FAIRVIEW LN
T52
AGUA CALIENTE CREEK
T51
T50
T49
OLD MAPLE AVE.
1-1
1-2
1-3
3-1
MAIN ST.
5-1
HARLEY ST.
1-5
1-3A
1-4
HWY 12
LOMITA AVE.
ROBINSON ROAD
VERANO AVE.
T48
VERANO AVE.
T47
EASEMENT
T46
T45
T44
T43
T42B
T42A
T42
T41
T40
66-1
SONOMA HWY.
2-66
N
NO SCALE
FIFTH STREET WEST
2-38
OAK ST.
2-39
2-40
WALNUT AVE.
SONOMA CREEK
2-41
SOLANO AVE.
RIVERSIDE DRIVE
2-63
2-64
2-65
WEST SPAIN ST.
65-1
64-1
T39
2-60
2-62
T38
2-67A
2-67
2-68
T37A
T37
67-1
WEST NAPA ST.
61-2
EASE
PETALUMA AVE.
61-1
2-61
T36
T35
STUDLEY ST.
LEGEND
ROADS
SEWER MAINS
MANHOLES
CLEANOUTS
PREFIX "T" = TRUNK LINE MH'S
" "1" = L.I.D. NO.1 MH'S
" "2" = L.I.D. NO.2 MH'S
" "3" = L.I.D. NO.3 MH'S
" "B" = BELAIRE SONOMA SUB'D. MH'S
" "M" = RANCHO MADRONE SUB'D. MH'S
To Santa Rosa
Glen Ellen
12
STATE HOME
MADRONE RD.
AGUA CALIENTE RD.
BOYES BLVD.
VERANO AVE.
PETALUMA AVE.
MOUNTAIN AVE.
SIESTA WAY
WEST NAPA ST
City of Sonoma
N
NO SCALE
LEVERONI RD.
WATMAUGH RD.
NAPA RD.
EIGHTH ST. E.
ADOBE RD.
To Santa Rosa
Petaluma
116
12/121
To Napa
CREEK
SONOMA
121
101
To San Rafael
LAKEVILLE RD.
To San Rafael
To Vallejo
37
SITE MAP

SM-2



LEGEND

ROADS

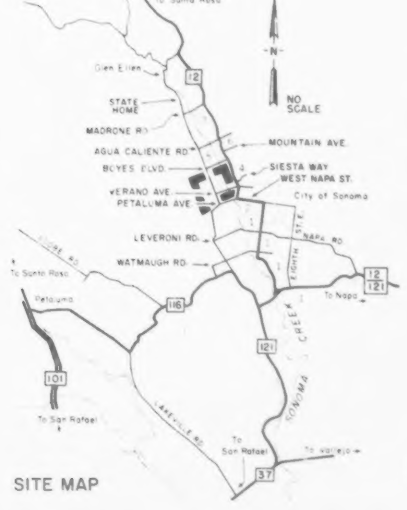
SEWER MAINS

MANHOLES

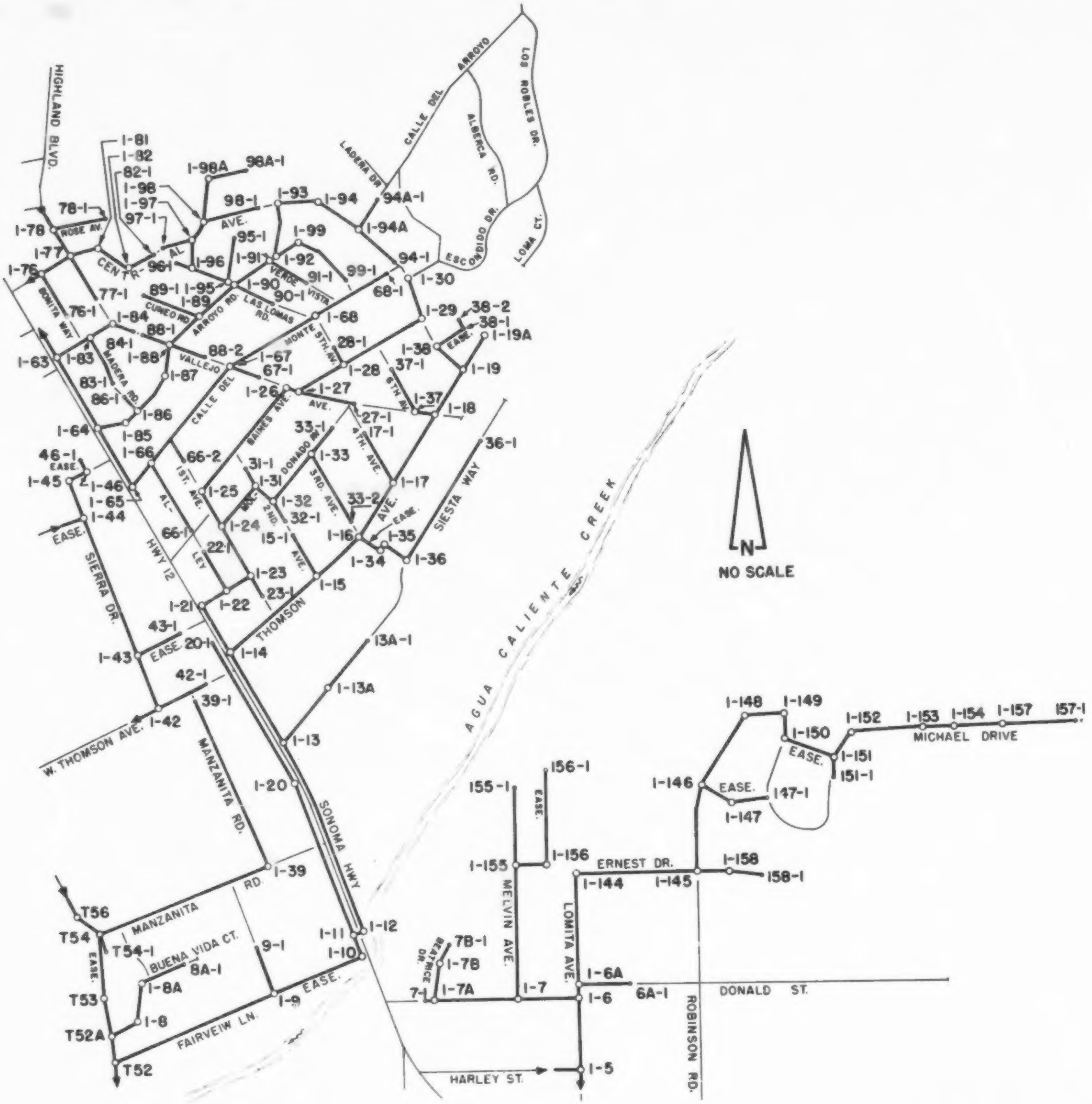
CLEANOUTS

PREFIX "T" = TRUNK LINE MH'S
" "1" = L.I.D. NO.1 MH'S
" "2" = L.I.D. NO.2 MH'S
" "3" = L.I.D. NO.3 MH'S
" "B" = BELAIRE SONOMA SUB'D. MH'S
" "M" = RANCHO MADRONE SUB'D. MH'S

SM-3



SITE MAP



LEGEND

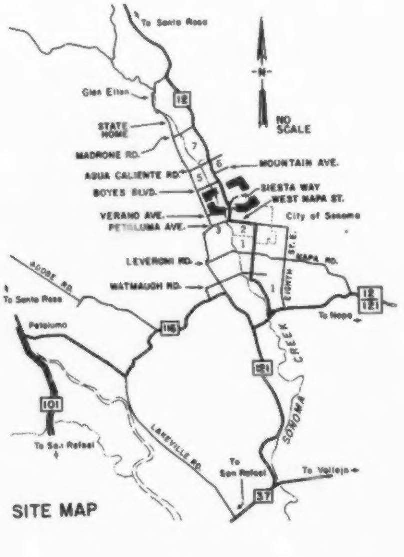
ROADS

SEWER MAINS

MANHOLES

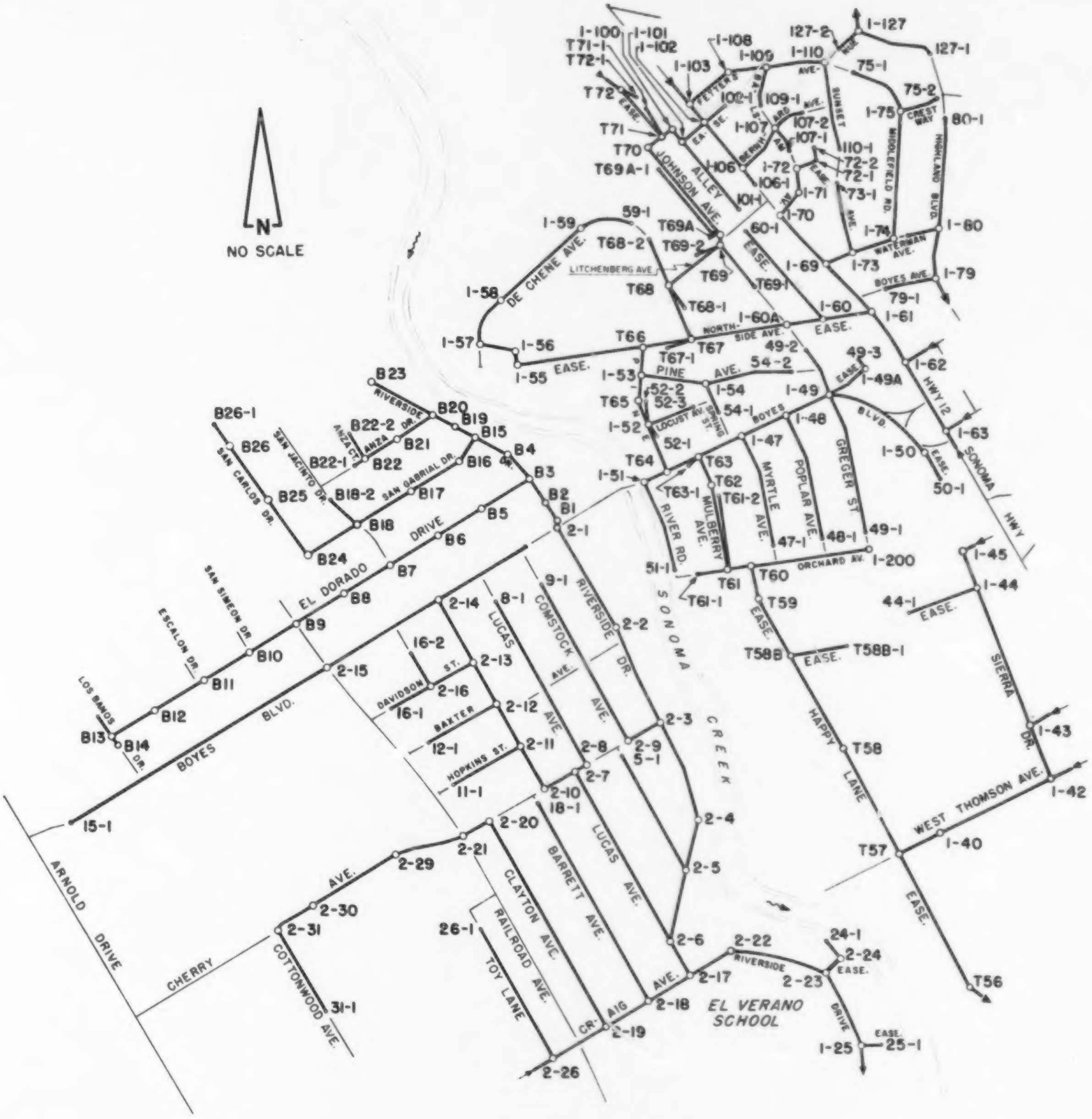
CLEANOUTS

PREFIX "T" = TRUNK LINE MH'S
" "1" = L.I.D. NO.1 MH'S
" "2" = L.I.D. NO.2 MH'S
" "3" = L.I.D. NO.3 MH'S
" "B" = BELAIRE SONOMA SUB'D. MH'S
" "M" = RANCHO MADRONE SUB'D. MH'S



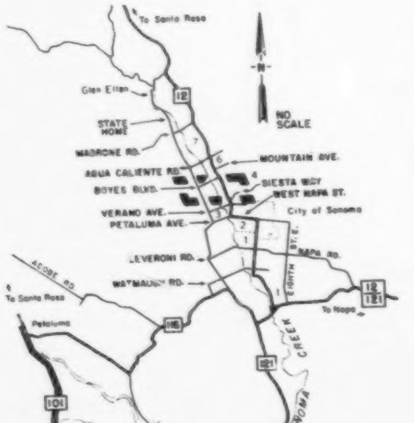
SITE MAP

SM-4



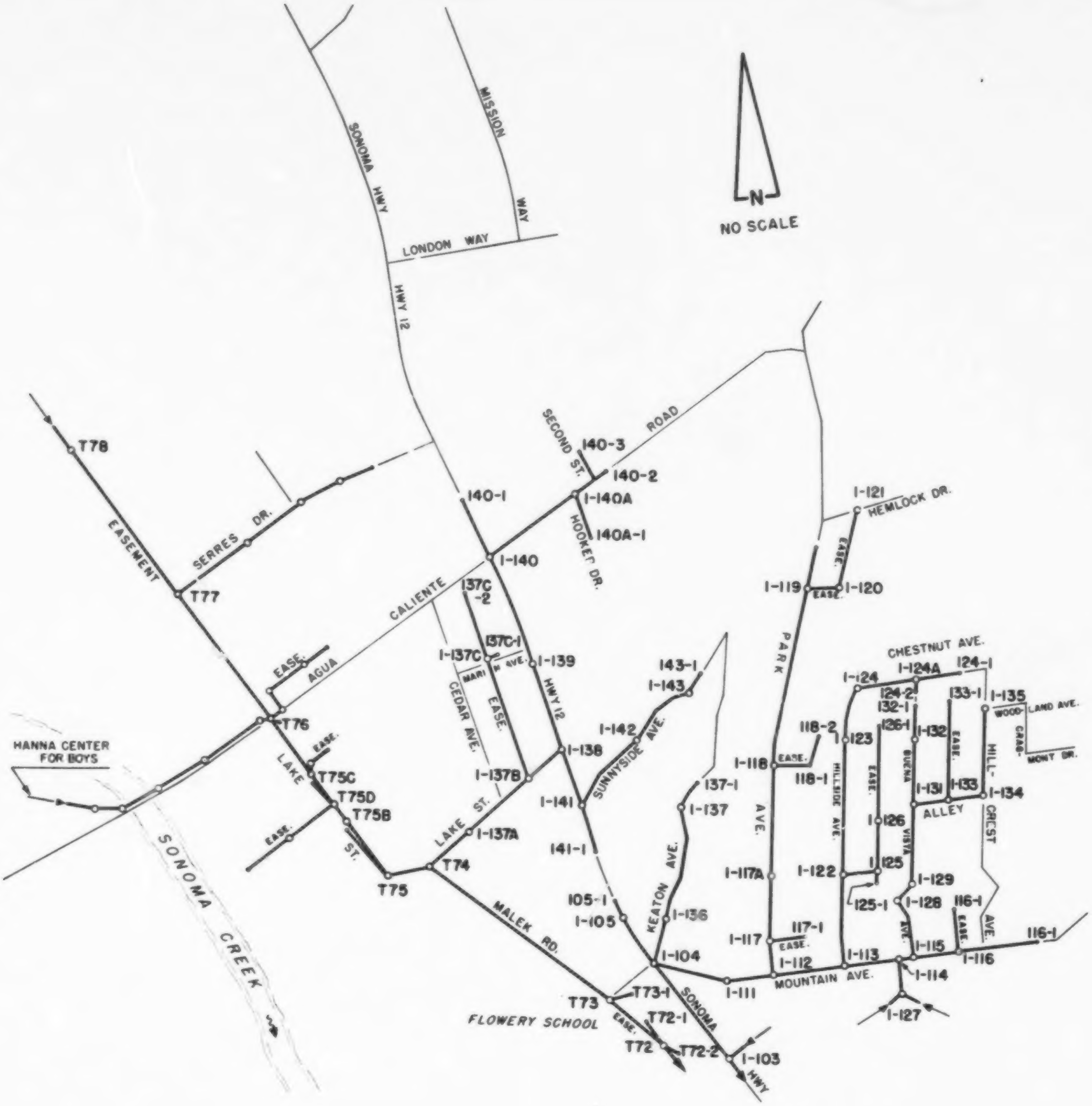
LEGEND

ROADS
SEWER MAINS
MANHOLES
CLEANOUTS
PREFIX "T" = TRUNK LINE MH'S
" "1" = L.I.D. NO.1 MH'S
" "2" = L.I.D. NO.2 MH'S
" "3" = L.I.D. NO.3 MH'S
" "B" = BELAIRE SONOMA SUB'D. MH'S
" "M" = RANCHO MADRONE SUB'D. MH'S



SM-5

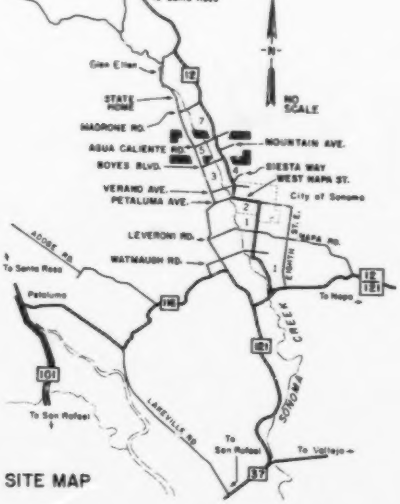
SITE MAP



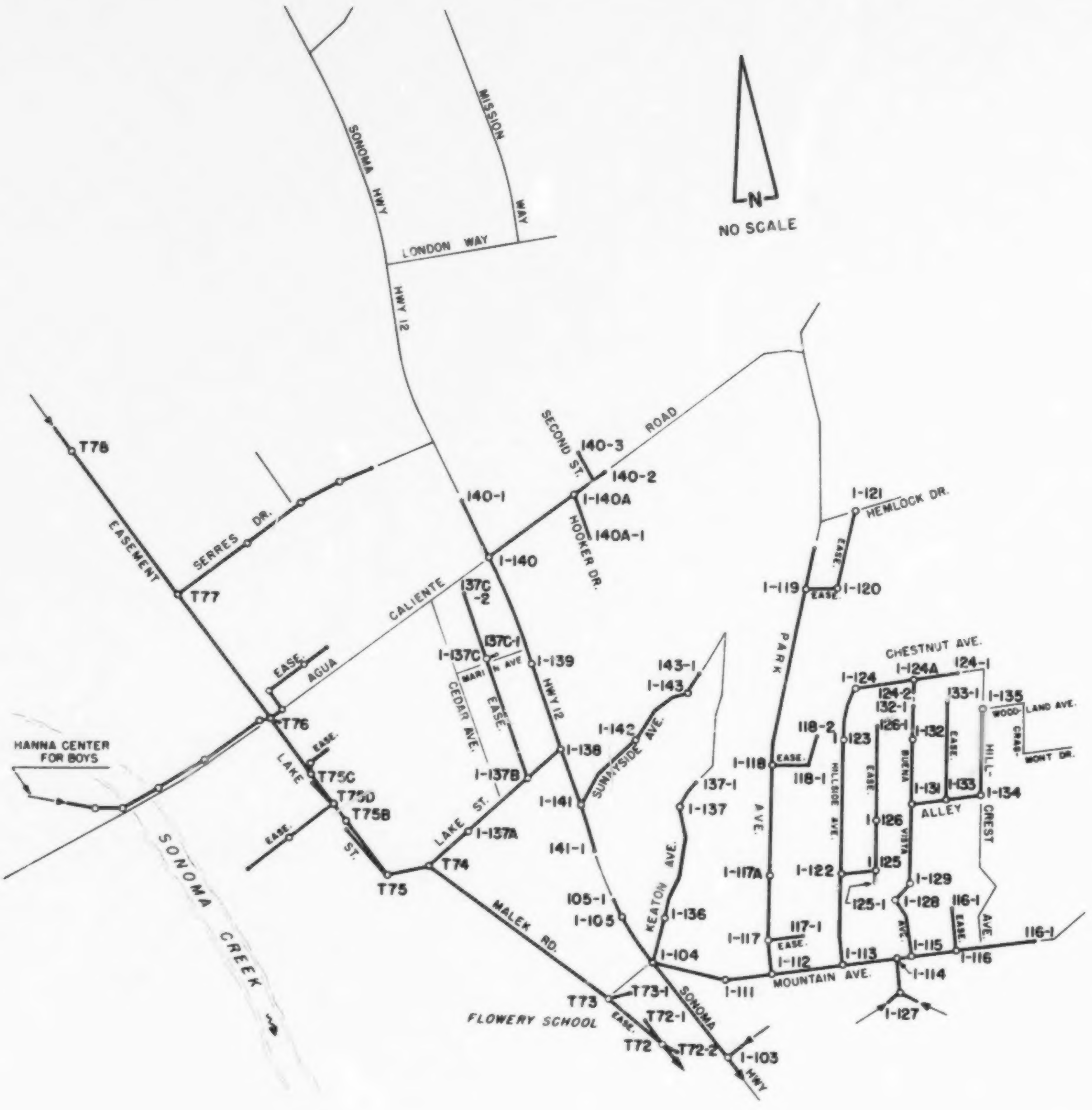
LEGEND

ROADS
SEWER MAINS
MANHOLES
CLEANOUTS

PREFIX "T" = TRUNK LINE MH'S
" "I" = L.I.D. NO.1 MH'S
" "2" = L.I.D. NO.2 MH'S
" "3" = L.I.D. NO.3 MH'S
" "B" = BELAIRE SONOMA SUB'D. MH'S
" "M" = RANCHO MADRONE SUB'D. MH'S

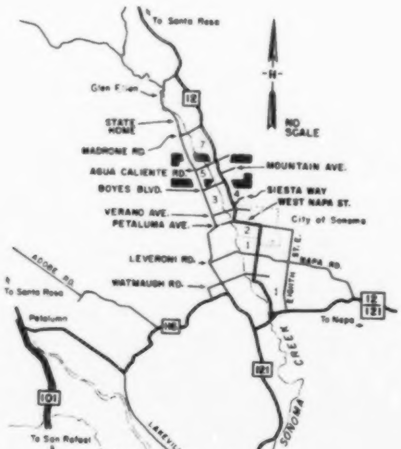


SITE MAP



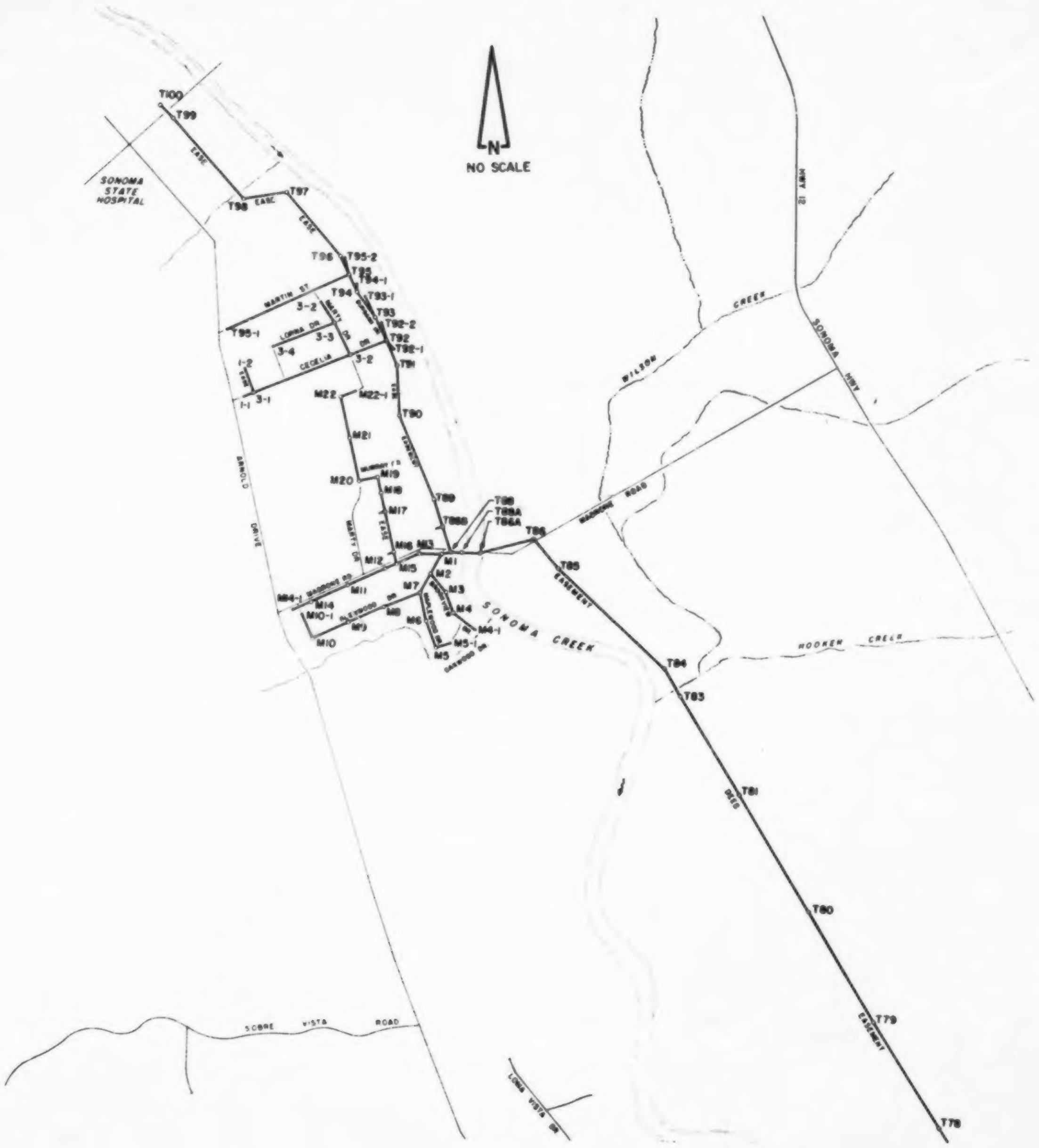
LEGEND

ROADS
SEWER MAINS
MANHOLES
CLEANOUTS
PREFIX "T" = TRUNK LINE MH'S
" "1" = L.I.D. NO.1 MH'S
" "2" = L.I.D. NO.2 MH'S
" "3" = L.I.D. NO.3 MH'S
" "B" = BELAIRE SONOMA SUB'D. MH'S
" "M" = RANCHO MADRONE SUB'D. MH'S



SITE MAP

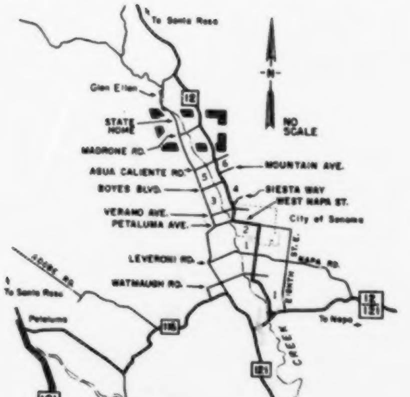
SM-6



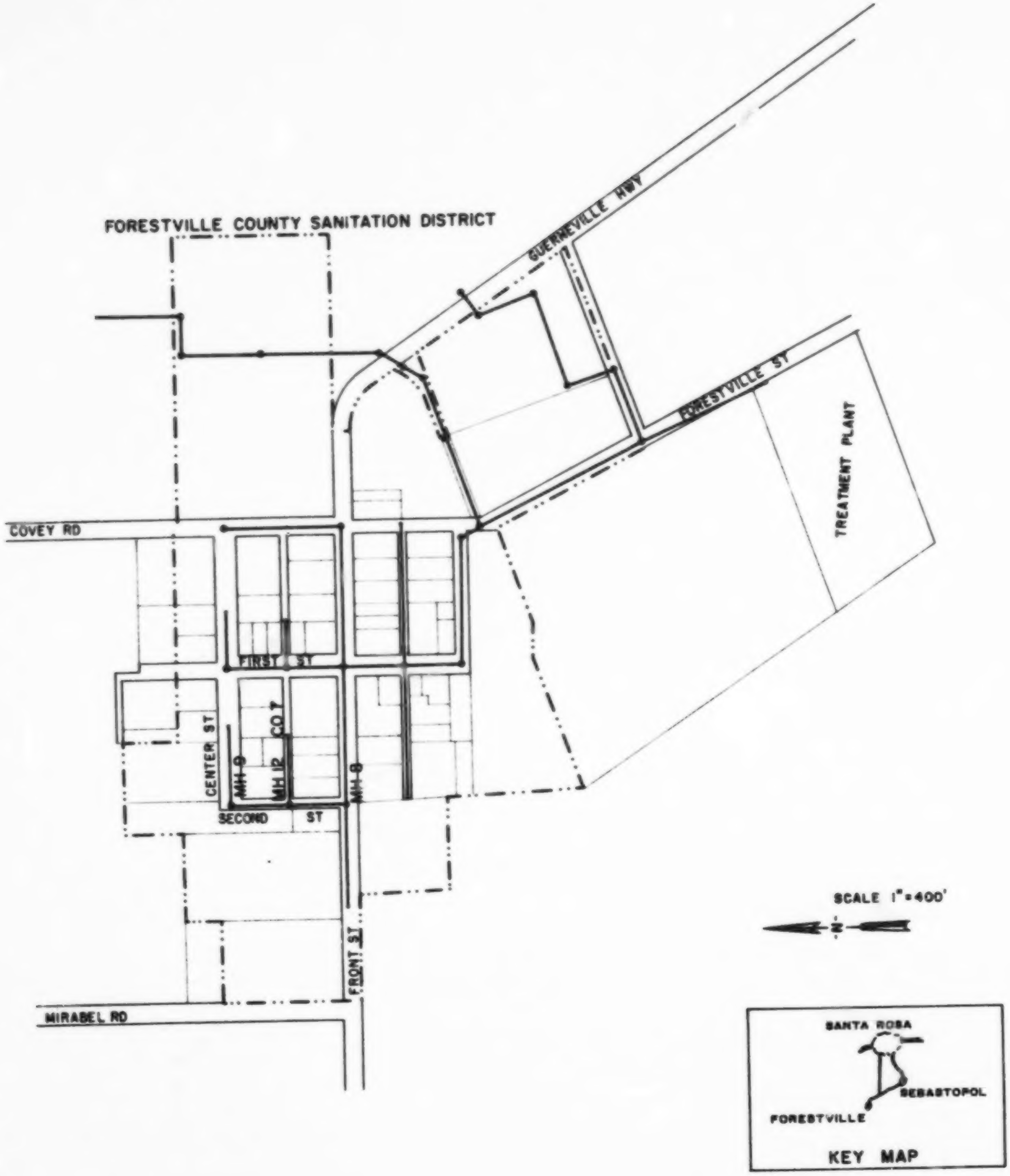
LEGEND

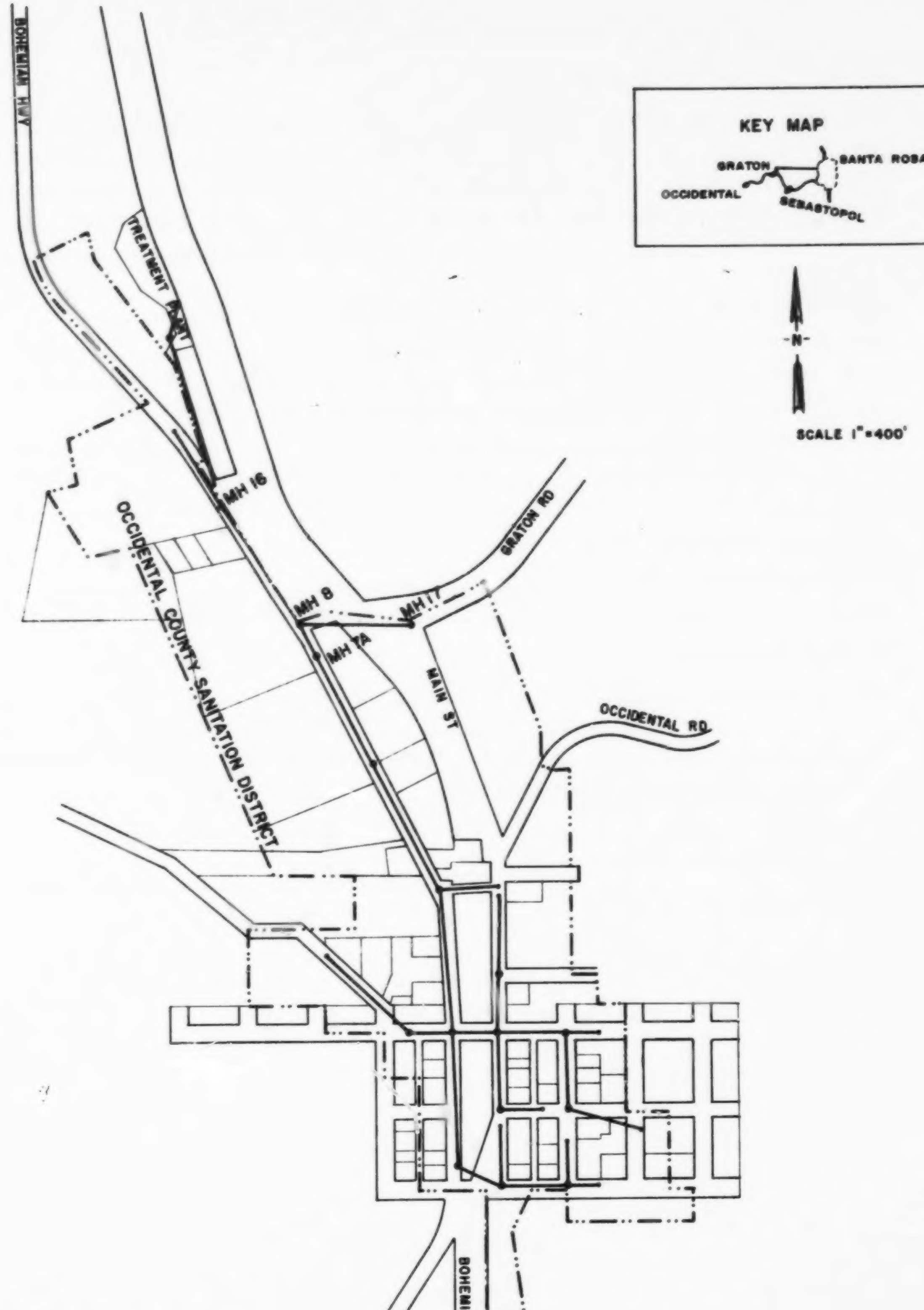
——— ROADS
——— SEWER MAINS
—o— MANHOLES
——o CLEANOUTS
PREFIX "T" = TRUNK LINE MH'S
" "1" = L.I.D. NO.1 MH'S
" "2" = L.I.D. NO.2 MH'S
" "3" = L.I.D. NO.3 MH'S
" "B" = BELAIRE SONOMA SUB'D. MH'S
" "M" = RANCHO MADRONE SUB'D. MH'S

SM-7



SITE MAP


FORESTVILLE COUNTY SANITATION DISTRICT
GUERNEVILLE HWY
FORESTVILLE ST
TREATMENT PLANT
COVEY RD
FIRST ST
CENTER ST
MH 9
MH 12
CO 7
MH 8
SECOND ST
FRONT ST
MIRABEL RD
SCALE 1" = 400'
N
SANTA ROSA
SEBASTOPOL
FORESTVILLE
KEY MAP



BOHEMIAN HWY
TREATMENT PLANT
MH 16
OCCIDENTAL COUNTY SANITATION DISTRICT
MH 8
MH 17
MH 7A
GRATON RD
MAIN ST
OCCIDENTAL RD
BOHEMIAN HWY
KEY MAP
GRATON
SANTA ROSA
OCCIDENTAL
SEBASTOPOL
N
SCALE 1"=400'

HYDROSTATIC TEST DATA

GENERAL INFORMATION:

TEST No. 1 DISTRICT OR IDENT. FORESTVILLE SANITATION DISTRICT

EST. TEMP. ______ °F TIME 9:05 A.M. DATE March 17, , 19 66

LOCATION OF SEWER LINE: Alley #4 Adjacent to Second STREET

BETWEEN MANHOLE No. 12 AND MANHOLE No. 7 OR CLEANOUT No. ______

DIFF. IN INVERT ELEVATION 4.6 FT.

DESCRIPTION OF SEWER INSTALLATION:

TYPE OF PIPE USED Vitrified Clay , 6 IN. DIA.

JOINT TYPE Mortar LENGTH OF LINE 159 FT.

LINE -*STRIKE OUT ONE*- ~~(WAS)~~ (WAS NOT) CLEANED BEFORE TESTING

METHOD OF CLEANING ______

TIME OF TEST: START 9:48 A.M. STOP 10:45 A.M. ELAPSED 57 Minutes

LOSS ______ GAL., LOSS ______ GAL./FT.

MATERIAL AROUND PIPE:

TYPE OF MATERIAL It appears to be Sandy Loam & Clay

MOISTURE CONTENT Damp

TRENCH BACKFILL:

TYPE OF MATERIAL It appears to be Sandy Loam & Clay

MOISTURE CONTENT Damp

PIPE BEDDING IS CONSIDERED TO BE IN A -*STRIKE OUT ALL BUT ONE*- ~~(DRY)~~ (DAMP) ~~(WET)~~ ~~(SATURATED) (OTHER - EXPLAIN)~~ CONDITION.

REMARKS:

	TIME (MIN. -SEC.)	DROP (IN.)	LOSS IN GPD P IN. DIA. OF PIPE P MILE.
1.	0:582	12"	120,630
2.	2:2985	22"	85,500
3.	4:5475	28"	55,600
Average			87,243

Vol. Cal. Based on a 6" Dia. C. O. Riser.

HT - 1

INSPECTOR J. R. Ward

HYDROSTATIC TEST DATA

GENERAL INFORMATION:

TEST No. 2 DISTRICT OR IDENT. FORESTVILLE SANITATION DISTRICT

EST. TEMP. ______ °F TIME 10:00 A.M. DATE October 11, , 19 66

LOCATION OF SEWER LINE: Alley #4 Adjacent to Second Street STREET

BETWEEN MANHOLE No. ______ AND MANHOLE No. ______ OR CLEANOUT No. ______

DIFF. IN INVERT ELEVATION ______ FT.

DESCRIPTION OF SEWER INSTALLATION:

TYPE OF PIPE USED Vitrified Clay , 6 IN. DIA.

JOINT TYPE Mortar LENGTH OF LINE 159 FT.

LINE -*STRIKE OUT ONE*- ~~(WAS)~~ (WAS NOT) CLEANED BEFORE TESTING

METHOD OF CLEANING Flushing

TIME OF TEST: START ______ STOP ______ ELAPSED ______

LOSS ______ GAL., LOSS ______ GAL./FT.

MATERIAL AROUND PIPE:

TYPE OF MATERIAL It appears to be Sandy Loam & Clay

______ MOISTURE CONTENT Damp

TRENCH BACKFILL:

TYPE OF MATERIAL It appears to be Sandy Loam & Clay

______ MOISTURE CONTENT Damp

PIPE BEDDING IS CONSIDERED TO BE IN A -*STRIKE OUT ALL BUT ONE*- ~~(DRY)~~ (DAMP) ~~(WET)~~ ~~(SATURATED)(OTHER-EXPLAIN)~~ CONDITION.

REMARKS:

	TIME (MIN. & SEC.)	DROP (IN.)	LOSS IN GPD P IN. DIA. OF PIPE P. MILE
1.	1:20"	7"	5,120.5
2.	3:42"	17"	4,480.1
3.	7:06"	23"	3,199.3
4.	1:21"	8"	5,780.1
5.	4:51"	18"	3,630.1
6.	7:54"	24"	2,962.3
7.	1:12"	6"	4,868.8
8.	3:38"	16"	4,294.1
9.	7:28"	24"	2,873.3
10.	0:35"	4"	6,686.4
11.	3:56"	18"	4,462.4
12.	9:30"	20"	2,052.8
		AVERAGE	4,682.9

HT - 2

INSPECTOR J. R. Ward

HYDROSTATIC TEST DATA

GENERAL INFORMATION:

TEST No. 2 DISTRICT OR IDENT. FORESTVILLE SANITATION DISTRICT

EST. TEMP. ______ °F TIME 10:00 A.M. DATE October 11, , 19 66

LOCATION OF SEWER LINE: Alley #4 Adjacent to Second Street STREET

BETWEEN MANHOLE No. ______ AND MANHOLE No. ______ OR CLEANOUT No. ______

DIFF. IN INVERT ELEVATION ______ FT.

DESCRIPTION OF SEWER INSTALLATION:

TYPE OF PIPE USED Vitrified Clay , 6 IN. DIA.

JOINT TYPE Mortar LENGTH OF LINE 159 FT.

LINE -*STRIKE OUT ONE* ~~(WAS)~~ (WAS NOT) CLEANED BEFORE TESTING

METHOD OF CLEANING Flushing

TIME OF TEST: START ______ STOP ______ ELAPSED ______

LOSS ______ GAL., LOSS ______ GAL./FT.

MATERIAL AROUND PIPE:

TYPE OF MATERIAL It appears to be Sandy Loam & Clay

MOISTURE CONTENT Damp

TRENCH BACKFILL:

TYPE OF MATERIAL It appears to be Sandy Loam & Clay

MOISTURE CONTENT Damp

PIPE BEDDING IS CONSIDERED TO BE IN A -*STRIKE OUT ALL BUT ONE*- ~~(DRY)~~ (DAMP) ~~(WET)~~ ~~(SATURATED)(OTHER-EXPLAIN)~~ CONDITION.

REMARKS:

	TIME (MIN. & SEC.)	DROP (IN.)	LOSS IN GPD P IN. DIA. OF PIPE P. MILE
1.	1:20"	7"	5,120.5
2.	3:42"	17"	4,480.1
3.	7:06"	23"	3,199.3
4.	1:21"	8"	5,780.1
5.	4:51"	18"	3,630.1
6.	7:54"	24"	2,962.3
7.	1:12"	6"	4,868.8
8.	3:38"	16"	4,294.1
9.	7:28"	24"	2,873.3
10.	0:35"	4"	6,686.4
11.	3:56"	18"	4,462.4
12.	9:30"	20"	2,052.8
		AVERAGE	4,682.9

INSPECTOR J. R. Ward

HYDROSTATIC TEST DATA

GENERAL INFORMATION:

TEST No. 1 DISTRICT OR IDENT. OCCIDENTAL SANITATION DISTRICT

EST. TEMP. ______ °F TIME 2:05 A.M. DATE March 15, 1966

LOCATION OF SEWER LINE: [illegible] STREET

BETWEEN MANHOLE No. [illegible] AND MANHOLE No. 17 OR CLEANOUT No. ______

DIFF. IN INVERT ELEVATION 5.02 FT.

DESCRIPTION OF SEWER INSTALLATION:

TYPE OF PIPE USED C.P., 6 IN. DIA.

JOINT TYPE Mortar LENGTH OF LINE 327.5 FT.

LINE -*STRIKE OUT ONE*- ~~(WAS)~~ (WAS NOT) CLEANED BEFORE TESTING

METHOD OF CLEANING ______

TIME OF TEST: START ______ STOP ______ ELAPSED ______

LOSS ______ GAL., LOSS ______ GAL./FT.

MATERIAL AROUND PIPE:

TYPE OF MATERIAL Information not available

MOISTURE CONTENT Damp

TRENCH BACKFILL:

TYPE OF MATERIAL Information not available

MOISTURE CONTENT Damp

PIPE BEDDING IS CONSIDERED TO BE IN A -*STRIKE OUT ALL BUT ONE*- ~~(DRY)~~ (DAMP) ~~(WET)~~ ~~(SATURATED) (OTHER - EXPLAIN)~~ CONDITION.

REMARKS:

	TIME	DROP	LOSS IN GPD P IN. DIA. OF PIPE P MILE.
1.	0:29	11"	
2.	0:34	11"	
3.	0:33	11"	
4.	0:33	11"	
5.	0:34	11"	
6.	0:34	11"	
Average			152,000

VOL. CAL. BASED ON A 24" DIA. M. H.

HT - 3

Reproduced from best available copy.

INSPECTOR J. R. Ward

HYDROSTATIC TEST DATA

GENERAL INFORMATION:

TEST No. 2 DISTRICT OR IDENT.. OCCIDENTAL SANITATION DISTRICT

EST. TEMP. ______ °F TIME 9:15 A.M. DATE Oct. 20, 19 66

LOCATION OF SEWER LINE: GRATON ROAD STREET

BETWEEN MANHOLE No. 8 AND MANHOLE No. 17 OR CLEANOUT No. ______

DIFF. IN INVERT ELEVATION 5.02 FT.

DESCRIPTION OF SEWER INSTALLATION:

TYPE OF PIPE USED C.P. , 6 IN. DIA.

JOINT TYPE Mortar LENGTH OF LINE 327.5 FT.

LINE - *STRIKE OUT ONE* - ~~(WAS)~~ (WAS NOT) CLEANED BEFORE TESTING

METHOD OF CLEANING ______

TIME OF TEST: START ______ STOP ______ ELAPSED ______

LOSS ______ GAL., LOSS ______ GAL./FT.

MATERIAL AROUND PIPE:

TYPE OF MATERIAL Samples taken indicate clay

MOISTURE CONTENT Damp

TRENCH BACKFILL:

TYPE OF MATERIAL Samples taken indicate clay

MOISTURE CONTENT wet

PIPE BEDDING IS CONSIDERED TO BE IN A - *STRIKE OUT ALL BUT ONE* - ~~(DRY)(DAMP)~~ (WET) ~~(SATURATED) (OTHER - EXPLAIN)~~ CONDITION.

REMARKS:

	TIME	DROP	LOSS IN GPD P IN DIA. OF PIPE P MILE.
1.	0:47	4.75"	
2.	0:30	4.00"	
3.	0:60	8.00"	AVG. 45,930

VOL. BASED ON 24" DIA. M. H.

HT - 4

INSPECTOR J. R. Ward

HYDROSTATIC TEST DATA

GENERAL INFORMATION:

TEST No. 1 DISTRICT OR IDENT. BODEGA BAY

EST. TEMP. ______ °F TIME 10:1[illegible] A.M. DATE June 7, , 19 66

LOCATION OF SEWER LINE: DORAN PARK STREET

BETWEEN MANHOLE No. 1 AND MANHOLE No. ______ OR CLEANOUT No. 1

DIFF. IN INVERT ELEVATION 2" FT.

DESCRIPTION OF SEWER INSTALLATION:

TYPE OF PIPE USED Vitrified Clay , 8 IN. DIA.

JOINT TYPE Mortar LENGTH OF LINE 45 FT.

LINE -*STRIKE OUT ONE*- ~~(WAS)~~ (WAS NOT) CLEANED BEFORE TESTING

METHOD OF CLEANING New Line

TIME OF TEST: START 10:19 A.M. STOP 10:34 A.M. ELAPSED 16 Min.

LOSS ______ GAL., LOSS ______ GAL./FT.

MATERIAL AROUND PIPE:

TYPE OF MATERIAL Pea Gravel

MOISTURE CONTENT Damp

TRENCH BACKFILL:

TYPE OF MATERIAL Sand

MOISTURE CONTENT Damp

PIPE BEDDING IS CONSIDERED TO BE IN A -*STRIKE OUT ALL BUT ONE*- ~~(DRY)~~ (DAMP) ~~(WET)~~ ~~(SATURATED) (OTHER-EXPLAIN)~~ CONDITION.

REMARKS:

	TIME	DROP	LOSS IN GPD P IN. DIA. OF PIPE P MILE
1.	0:065	10"	344,814
2.	0:074	11"	
3.	0:080	12"	
4.	0:082	11"	
5.	0:082	11"	

VOL. CAL. BASED ON A 6" C. O. RISER FOR DIA.

HT - [illegible]

INSPECTOR J. R. Ward

HYDROSTATIC TEST DATA

GENERAL INFORMATION:

TEST No. 2 DISTRICT OR IDENT. BODEGA BAY

EST. TEMP. ______ °F TIME 12:00 DATE Oct. 6 , 19 66

LOCATION OF SEWER LINE: Doran Park STREET

BETWEEN MANHOLE No. 1 AND MANHOLE No. ______ OR CLEANOUT No. 1

DIFF. IN INVERT ELEVATION 2" FT.

DESCRIPTION OF SEWER INSTALLATION:

TYPE OF PIPE USED Vitrified Clay , 8 IN. DIA.

JOINT TYPE Mortar LENGTH OF LINE 45 FT.

LINE -*STRIKE OUT ONE*- ~~(WAS)~~ (WAS NOT) CLEANED BEFORE TESTING

METHOD OF CLEANING New line was flushed during sealing operation.

TIME OF TEST: START 12:00 STOP 2:43 A.M. ELAPSED ______

LOSS ______ GAL., LOSS ______ GAL./FT.

MATERIAL AROUND PIPE:

TYPE OF MATERIAL Pea Gravel

MOISTURE CONTENT Damp

TRENCH BACKFILL:

TYPE OF MATERIAL Sand

MOISTURE CONTENT Damp

PIPE BEDDING IS CONSIDERED TO BE IN A -*STRIKE OUT ALL BUT ONE*- ~~(DRY)~~ (DAMP) ~~(WET)~~ ~~(SATURATED) (OTHER-EXPLAIN)~~ CONDITION.

REMARKS:

	TIME	DROP	LOSS IN GPD P IN. DIA. OF PIPE P MILE.
1.	17'	1-3/16"	2,167

VOL. CAL. BASED ON 6" DIA. SWEEP (NOTE REST OF PIPE 8"DIA.)
VOL. = 1.746 Gals. for 0.1' Depth

INSPECTOR J. R. Ward

HYDROSTATIC TEST DATA

GENERAL INFORMATION:

TEST No. 3 DISTRICT OR IDENT. BODEGA BAY

EST. TEMP. ____ °F TIME 10:00 A.M. DATE Oct. 14, 19 66

LOCATION OF SEWER LINE: Bodega Bay Doran Park STREET

BETWEEN MANHOLE No. 1 AND MANHOLE No. ____ OR CLEANOUT No. 1

DIFF. IN INVERT ELEVATION 2" FT.

DESCRIPTION OF SEWER INSTALLATION:

TYPE OF PIPE USED Vitrified Clay, 8 IN. DIA.

JOINT TYPE Mortar LENGTH OF LINE 45 FT.

LINE -*STRIKE OUT ONE*- ~~(WAS)~~ (WAS NOT) CLEANED BEFORE TESTING

METHOD OF CLEANING ____

TIME OF TEST: START 10:30 A.M. STOP 1:30 P.M. ELAPSED 3 Hours

LOSS ____ GAL., LOSS ____ GAL./FT.

MATERIAL AROUND PIPE:

TYPE OF MATERIAL Pea Gravel

MOISTURE CONTENT Damp

TRENCH BACKFILL:

TYPE OF MATERIAL Sand

MOISTURE CONTENT Damp

PIPE BEDDING IS CONSIDERED TO BE IN A -*STRIKE OUT ALL BUT ONE*- ~~(DRY)~~ (DAMP) ~~(WET)~~ ~~(SATURATED) (OTHER-*EXPLAIN*)~~ CONDITION.

REMARKS:

NO INFILTRATION

100

HT - 7

INSPECTOR J. R. Ward

HYDROSTATIC TEST DATA

GENERAL INFORMATION:

TEST No. 1 DISTRICT OR IDENT. SONOMA VALLEY

EST. TEMP. ____ °F TIME 1:00 P.M. DATE April 15, , 19 66

LOCATION OF SEWER LINE: CECELIA DRIVE STREET

BETWEEN MANHOLE No. 92E AND MANHOLE No. 3-2 OR CLEANOUT No. ____

DIFF. IN INVERT ELEVATION 2.54 FT.

DESCRIPTION OF SEWER INSTALLATION:

TYPE OF PIPE USED Vitrified Clay , 6 IN. DIA.

JOINT TYPE Mortar LENGTH OF LINE 299 FT.

LINE -*STRIKE OUT ONE*- (WAS) ~~(WAS NOT)~~ CLEANED BEFORE TESTING

METHOD OF CLEANING Brushed

TIME OF TEST: START ____ STOP ____ ELAPSED ____

LOSS ____ GAL., LOSS ____ GAL./FT.

MATERIAL AROUND PIPE:

TYPE OF MATERIAL Clayey in appearance

MOISTURE CONTENT Damp

TRENCH BACKFILL:

TYPE OF MATERIAL Clayey in appearance

MOISTURE CONTENT Damp

PIPE BEDDING IS CONSIDERED TO BE IN A -*STRIKE OUT ALL BUT ONE* ~~(DRY)~~ (DAMP) ~~(WET)~~ ~~(SATURATED)(OTHER-EXPLAIN)~~ CONDITION.

REMARKS:

	TIME	DROP	LOSS IN GPD P IN. DIA. PIPE P MILE.
1.	0:22	0.1'	90,465
2.	1:11	0.2'	56,000
3.	2:16	0.3'	44,002
4.	3:38	0.4'	36,519
5.	1:08	0.1'	28,059
Average			59,000

VOL. CAL. BASED ON 48" DIA. M. H.

HT - 8

INSPECTOR J. R. Ward

HYDROSTATIC TEST DATA

GENERAL INFORMATION:

TEST No. 2 DISTRICT OR IDENT. SONOMA VALLEY

EST. TEMP. ______ °F TIME 1:30 P.M. DATE Nov. 1, 1966

LOCATION OF SEWER LINE: CECELIA DRIVE STREET

BETWEEN MANHOLE No. 92 E AND MANHOLE No. 3-2 OR CLEANOUT No. ______

DIFF. IN INVERT ELEVATION 2.54 FT.

DESCRIPTION OF SEWER INSTALLATION:

TYPE OF PIPE USED Vitrified Clay, 6 IN. DIA.

JOINT TYPE Mortar LENGTH OF LINE 299 FT.

LINE -*STRIKE OUT ONE*- (WAS) (~~WAS NOT~~) CLEANED BEFORE TESTING

METHOD OF CLEANING Brushed out before line sealing began

TIME OF TEST: START ______ STOP ______ ELAPSED ______

LOSS ______ GAL., LOSS ______ GAL./FT.

MATERIAL AROUND PIPE:

TYPE OF MATERIAL Clayey in appearance

MOISTURE CONTENT Damp

TRENCH BACKFILL:

TYPE OF MATERIAL Clayey in appearance

MOISTURE CONTENT Damp

PIPE BEDDING IS CONSIDERED TO BE IN A -*STRIKE OUT ALL BUT ONE*- (~~DRY~~)(DAMP)(~~WET~~) (~~SATURATED~~)(~~OTHER-EXPLAIN~~) CONDITION.

REMARKS:

	TIME	DROP	LOSS IN GPD P IN. DIA. PIPE PER MILE
1.	2:53	0.1'	13,933.
2.	1:60	0.1'	9,435.
3.	2.41	0.1'	5,765.
4.	3:64	0.1'	3,977.
5.	3:22	0.1'	3,045.
Average			7,231.

VOL. USED FOR CAL. = 9.39 Gals. This is for a depth of 0.1' in a 48" M.H.

INSPECTOR J. R. Ward

HYDROSTATIC TEST DATA

GENERAL INFORMATION:

TEST No. 1 DISTRICT OR IDENT. SONOMA VALLEY

EST. TEMP. ____ °F TIME ____ DATE April 19, , 19 66

LOCATION OF SEWER LINE: CECELIA DRIVE STREET

BETWEEN MANHOLE No. 3-2 AND MANHOLE No. 92D OR CLEANOUT No. ____

DIFF. IN INVERT ELEVATION 6.44 FT.

DESCRIPTION OF SEWER INSTALLATION:

TYPE OF PIPE USED Vitrified Clay , 6 IN. DIA.

JOINT TYPE Mortar LENGTH OF LINE 247.1 FT.

LINE -*STRIKE OUT ONE*- ~~(WAS)~~ (WAS NOT) CLEANED BEFORE TESTING

METHOD OF CLEANING ____

TIME OF TEST: START ____ STOP ____ ELAPSED ____

LOSS ____ GAL., LOSS ____ GAL./FT.

MATERIAL AROUND PIPE:

TYPE OF MATERIAL Unable to state type of material at this time.

MOISTURE CONTENT Damp

TRENCH BACKFILL:

TYPE OF MATERIAL Unable to state type of material at this time.

MOISTURE CONTENT Damp

PIPE BEDDING IS CONSIDERED TO BE IN A -*STRIKE OUT ALL BUT ONE*- ~~(DRY)~~ (DAMP) ~~(WET)~~ ~~(SATURATED)~~ ~~(OTHER-*EXPLAIN*)~~ CONDITION.

REMARKS:

	TIME	DROP	LOSS IN GPH P IN. DIA. OF PIPE P MILE.
1.	0:18	0.1'	160,500
2.	0:38	0.3'	229,000
3.	0:47	0.4'	243,370
4.	1:01	0.5'	239,000
5.	1:18	0.6'	222,000
Average			218,774

VOL. CAL. BASED ON 48" DIA. M. H.

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INSPECTOR J. R. Ward

HYDROSTATIC TEST DATA

GENERAL INFORMATION:

TEST No. 2 DISTRICT OR IDENT. SONOMA VALLEY

EST. TEMP. ______ °F TIME 9:00 A.M. DATE Nov. 1, 19 66

LOCATION OF SEWER LINE: CECELIA DRIVE STREET

BETWEEN MANHOLE No. 3-2 AND MANHOLE No. 92D OR CLEANOUT No. ______

DIFF. IN INVERT ELEVATION 6.44 FT.

DESCRIPTION OF SEWER INSTALLATION:

TYPE OF PIPE USED Vitrified Clay, 6 IN. DIA.

JOINT TYPE Mortar LENGTH OF LINE 247.1 FT.

LINE -*STRIKE OUT ONE*- ~~(WAS)~~ (WAS NOT) CLEANED BEFORE TESTING

METHOD OF CLEANING ______

TIME OF TEST: START ______ STOP ______ ELAPSED ______

LOSS ______ GAL., LOSS ______ GAL./FT.

MATERIAL AROUND PIPE:

TYPE OF MATERIAL Appears to be clay

MOISTURE CONTENT Damp

TRENCH BACKFILL:

TYPE OF MATERIAL Appears to be clay

MOISTURE CONTENT Damp

PIPE BEDDING IS CONSIDERED TO BE IN A -*STRIKE OUT ALL BUT ONE*- ~~(DRY)~~ (DAMP) ~~(WET)~~ ~~(SATURATED)~~ ~~(OTHER - EXPLAIN)~~ CONDITION.

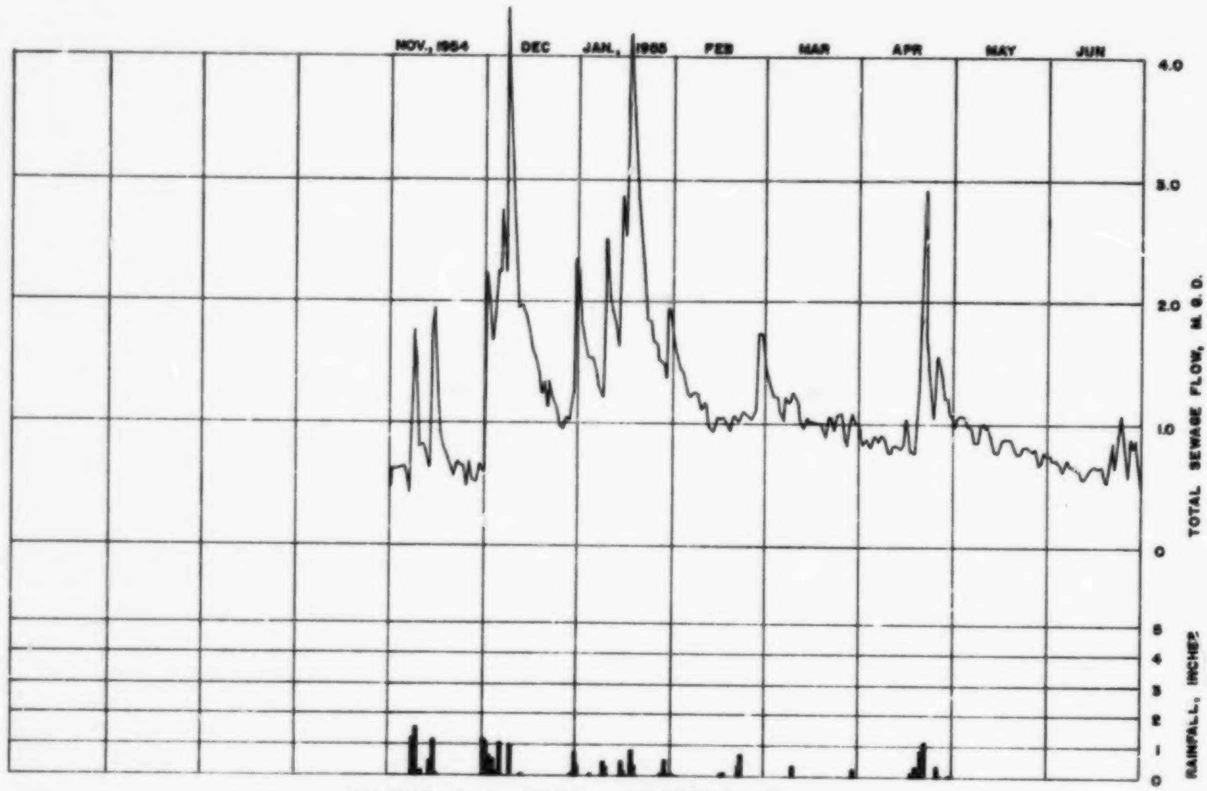
REMARKS:

	TIME	DROP	LOSS IN GPD P IN. DIA. OF PIPE P MILE.
1.	0:41	0.1'	70,443
2.	0:42	0.1'	68,763
3.	0:52	0.1'	55,582
4.	0:79	0.1'	36,576
5.	0:97	0.1'	29,787
Average			52,230

VOL. USED FOR CAL. = 9.39 GAL. FOR A 0.1' DEPTH IN A 48" M.H.

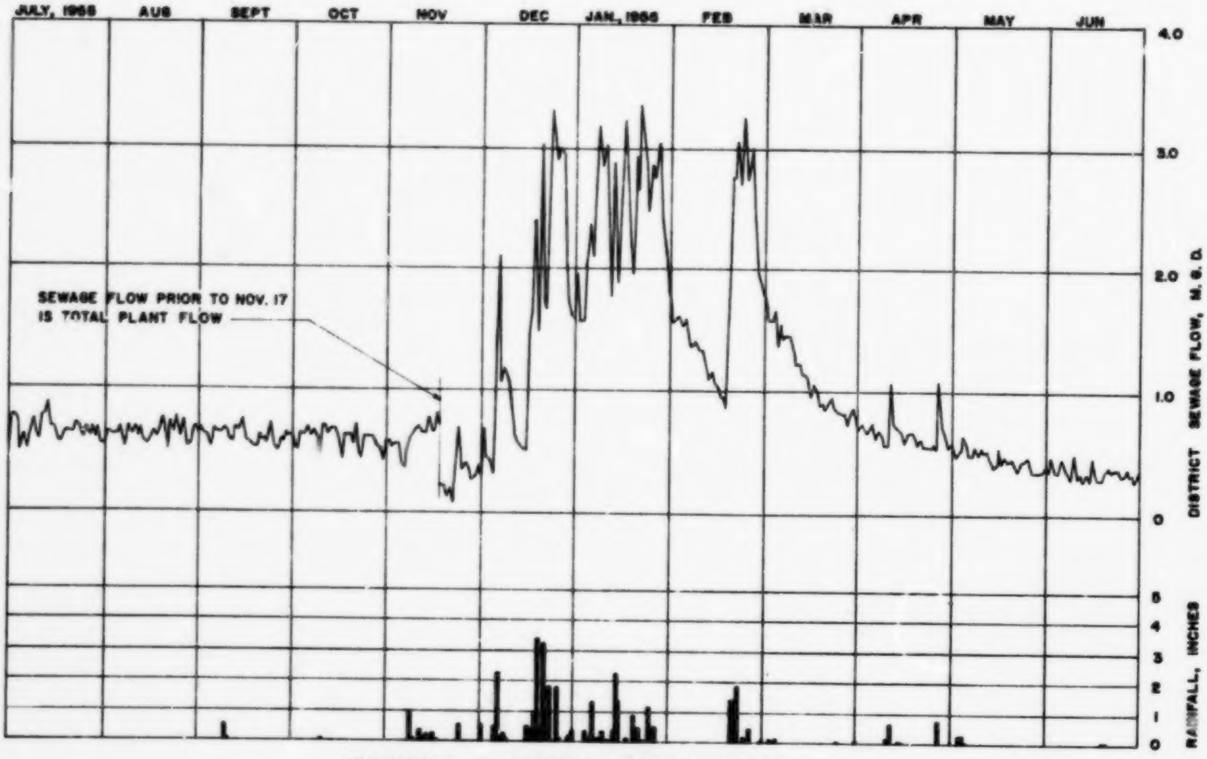
HT - 11

INSPECTOR J. R. Ward



RAINFALL & TOTAL SEWAGE FLOW

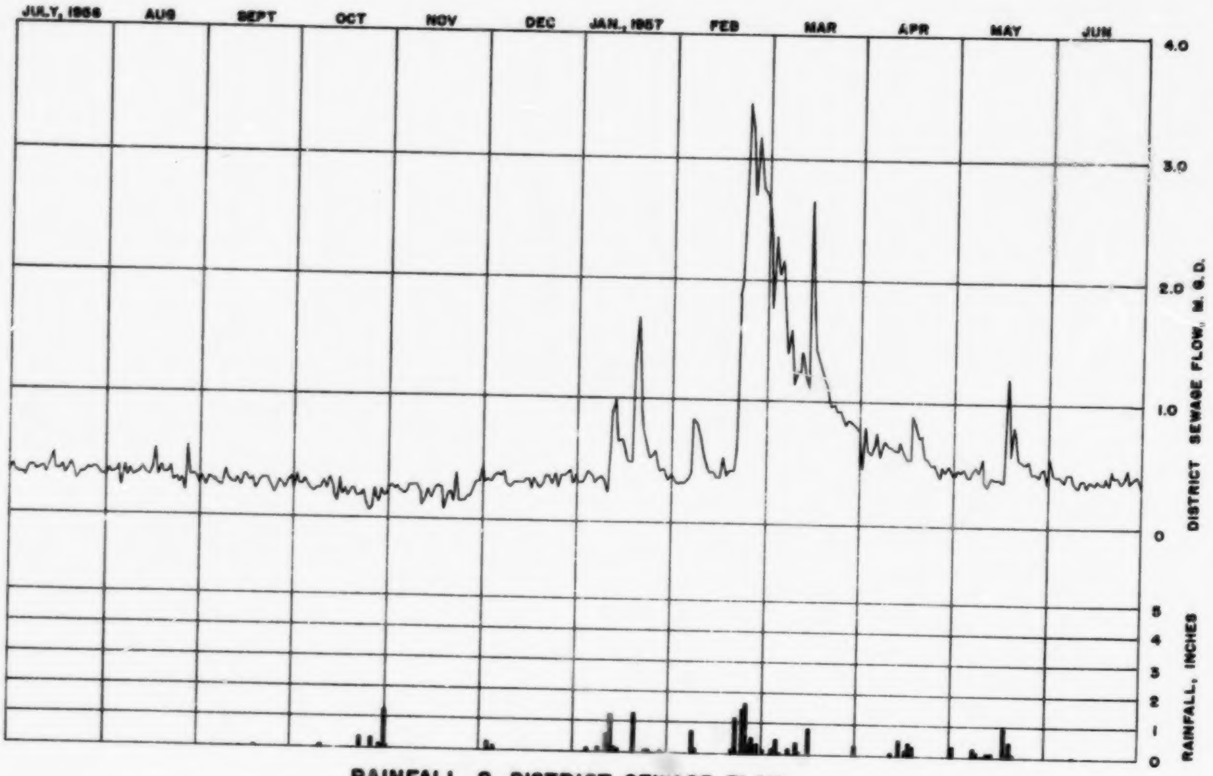
NOVEMBER, 1954 THRU JUNE, 1955



RAINFALL & DISTRICT SEWAGE FLOW

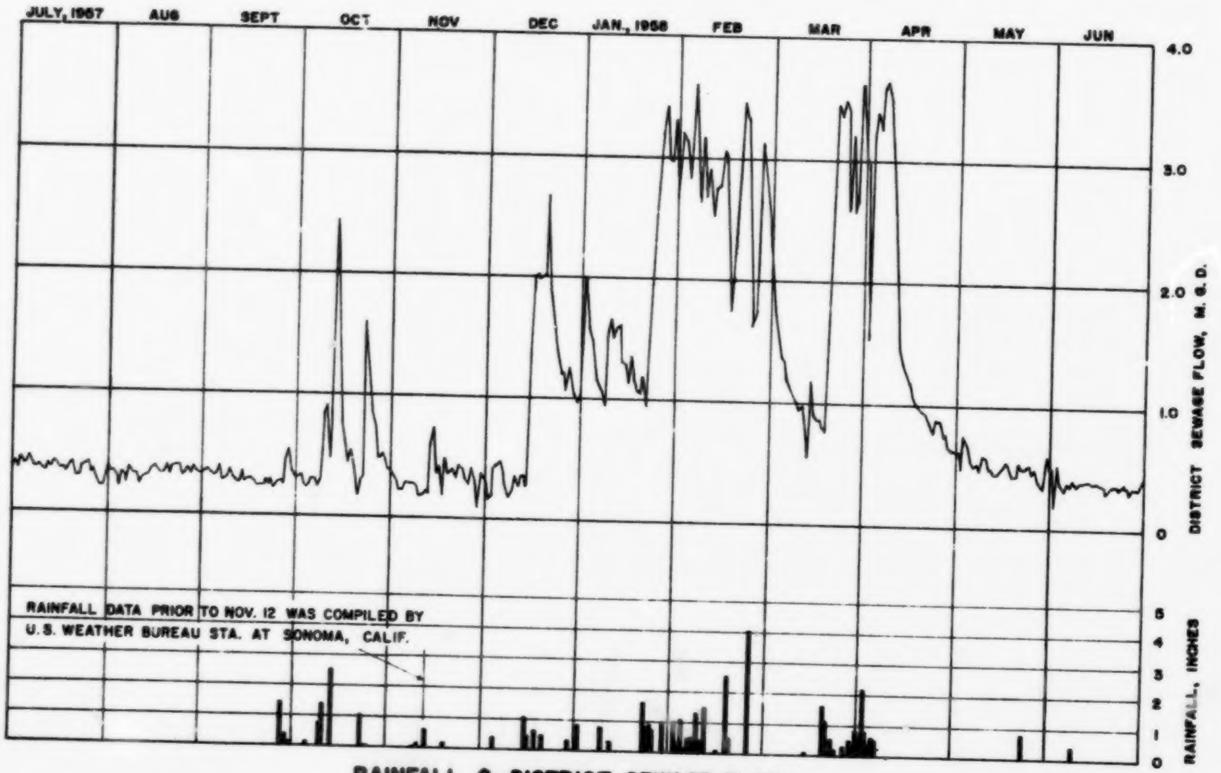
JULY, 1955 THRU JUNE, 1956

RF 1



RAINFALL & DISTRICT SEWAGE FLOW

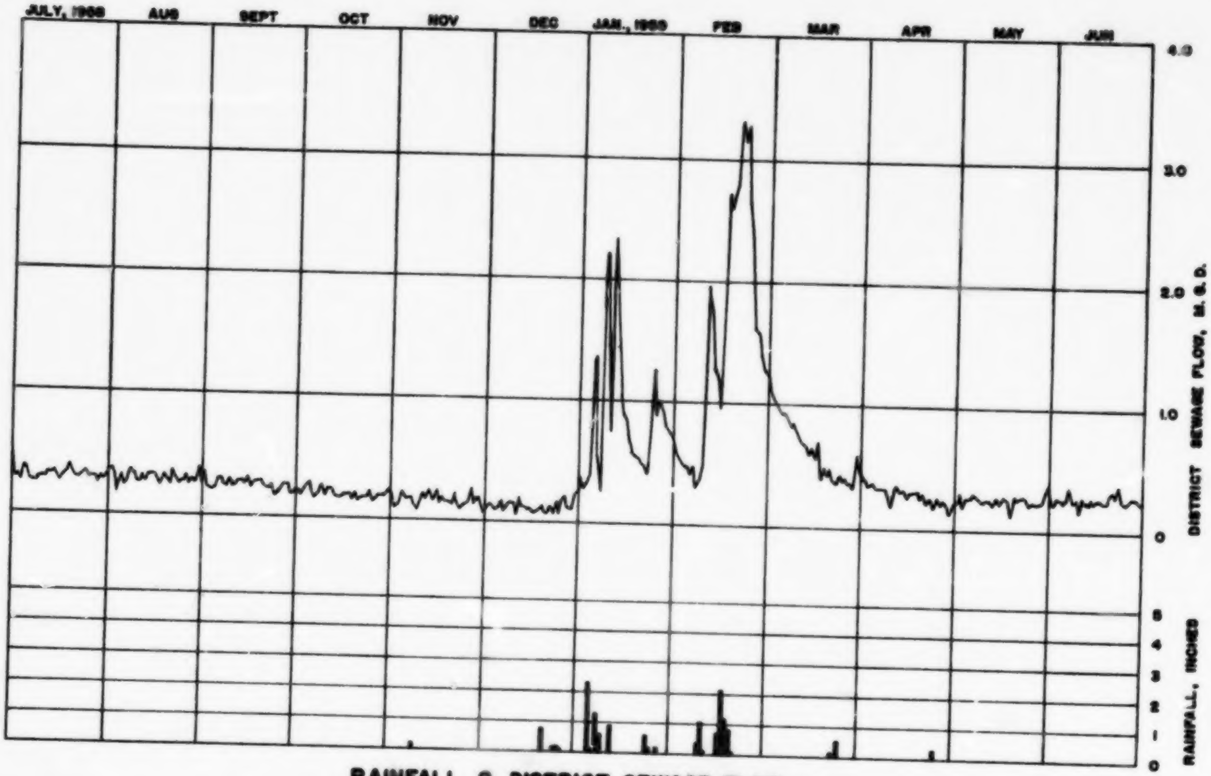
JULY, 1956 THRU JUNE, 1957



RAINFALL DATA PRIOR TO NOV. 12 WAS COMPILED BY
U.S. WEATHER BUREAU STA. AT SONOMA, CALIF.

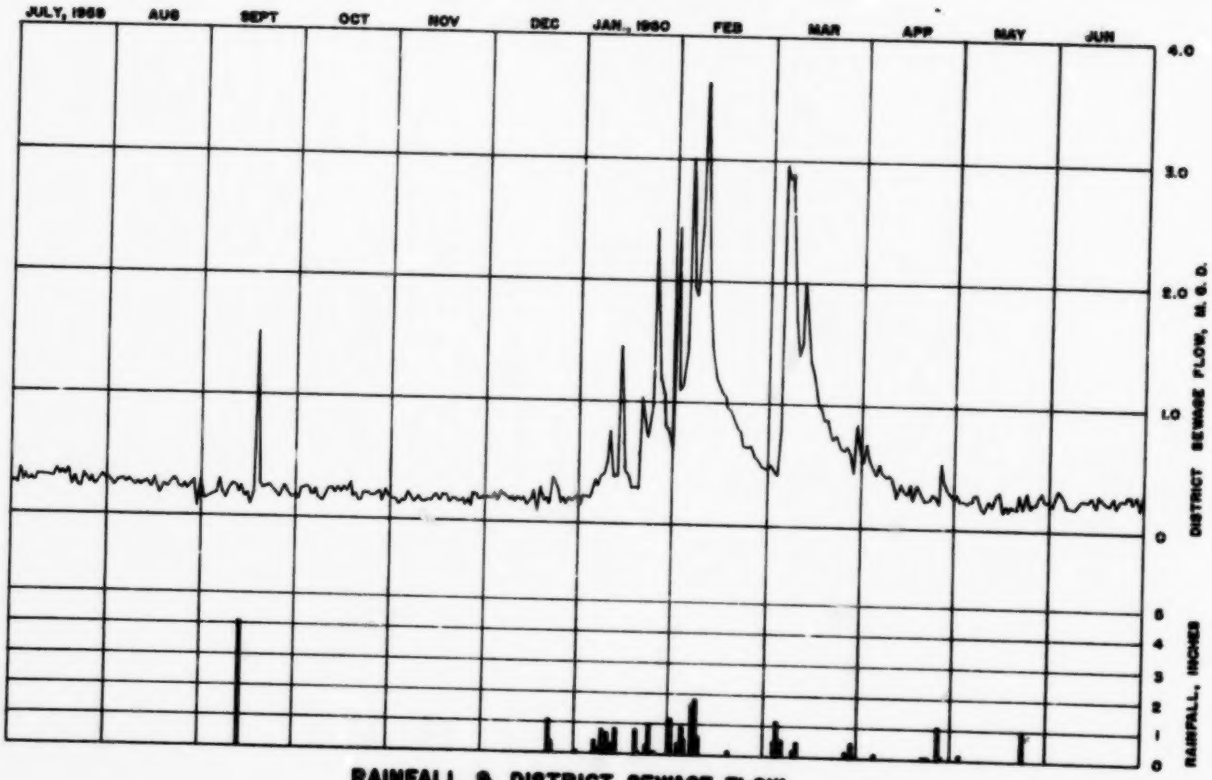
RAINFALL & DISTRICT SEWAGE FLOW

JULY, 1957 THRU JUNE, 1958



RAINFALL & DISTRICT SEWAGE FLOW

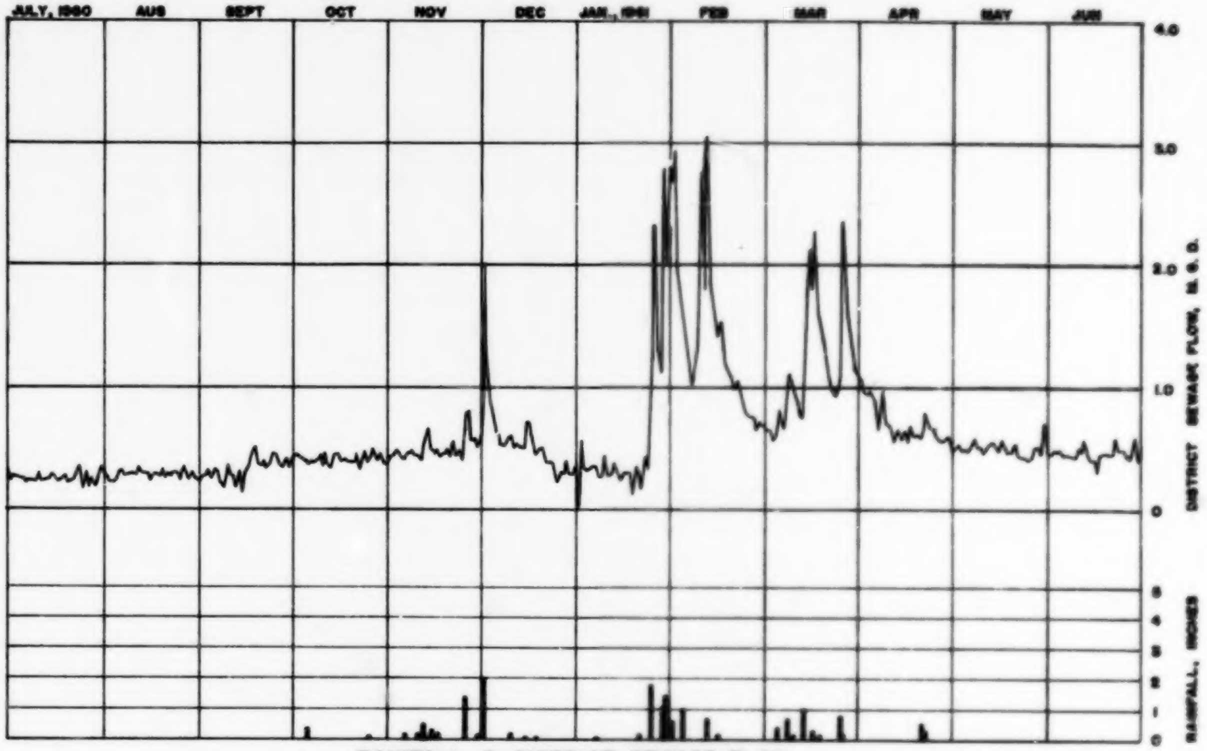
JULY, 1958 THRU JUNE, 1959



RAINFALL & DISTRICT SEWAGE FLOW

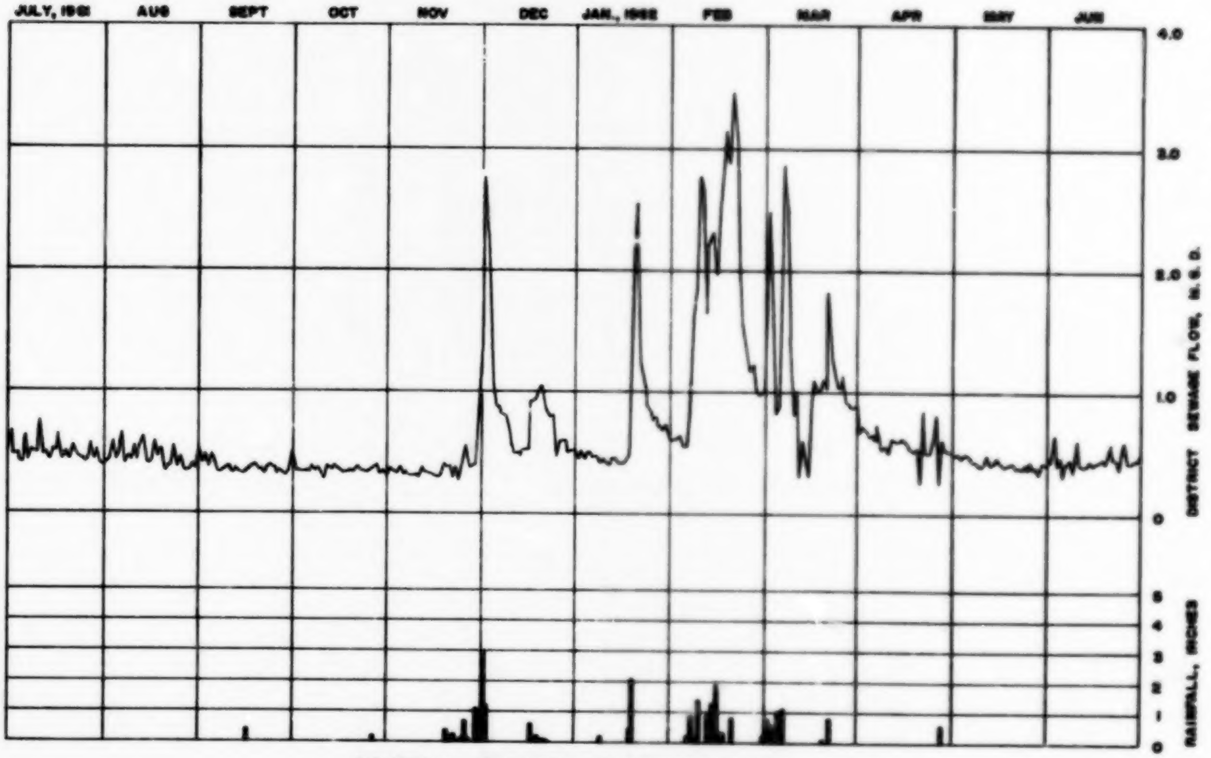
JULY, 1959 THRU JUNE, 1960

RF 3



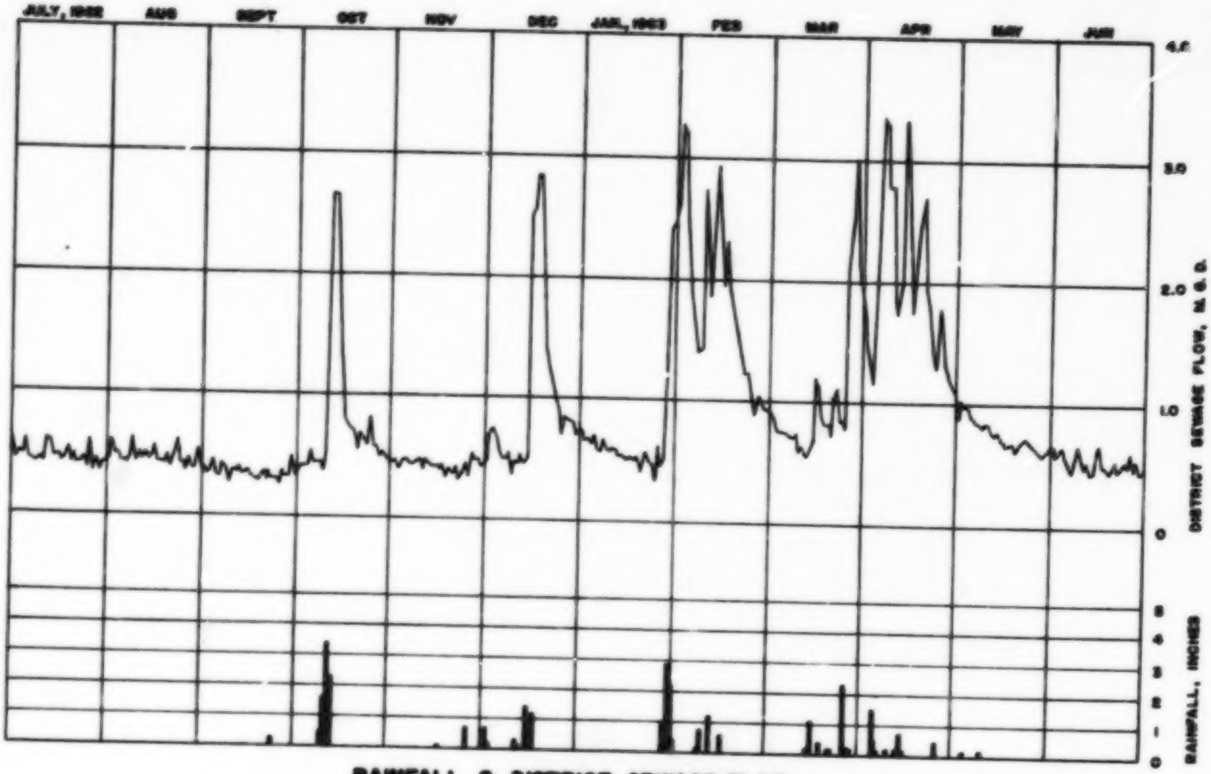
RAINFALL & DISTRICT SEWAGE FLOW

JULY, 1960 THRU JUNE, 1961



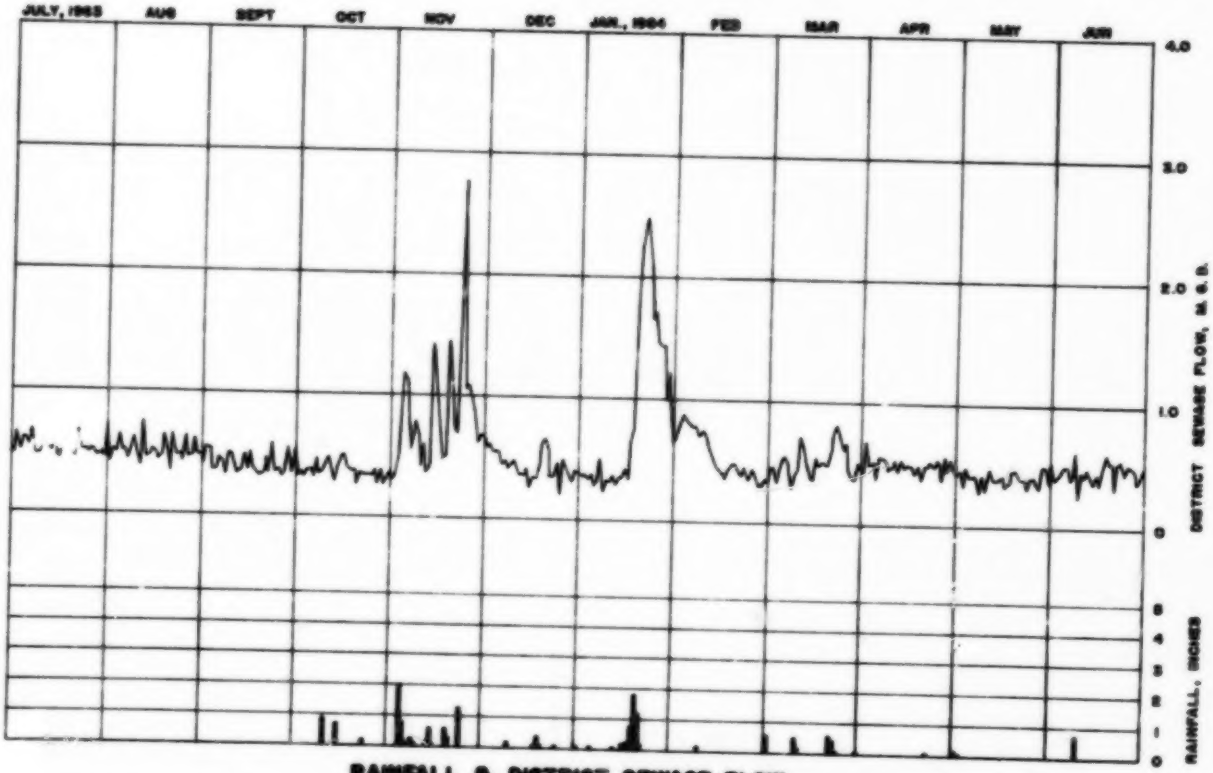
RAINFALL & DISTRICT SEWAGE FLOW

JULY, 1961 THRU JUNE, 1962



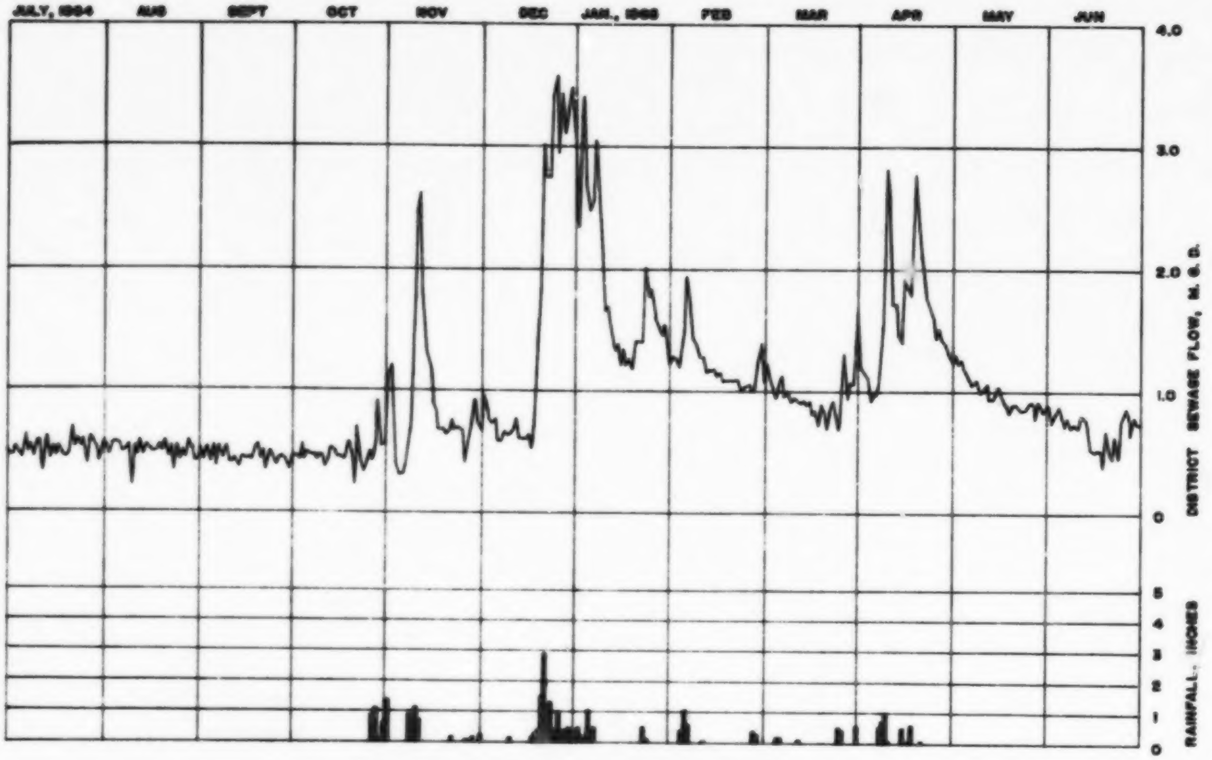
RAINFALL & DISTRICT SEWAGE FLOW

JULY, 1962 THRU JUNE, 1963



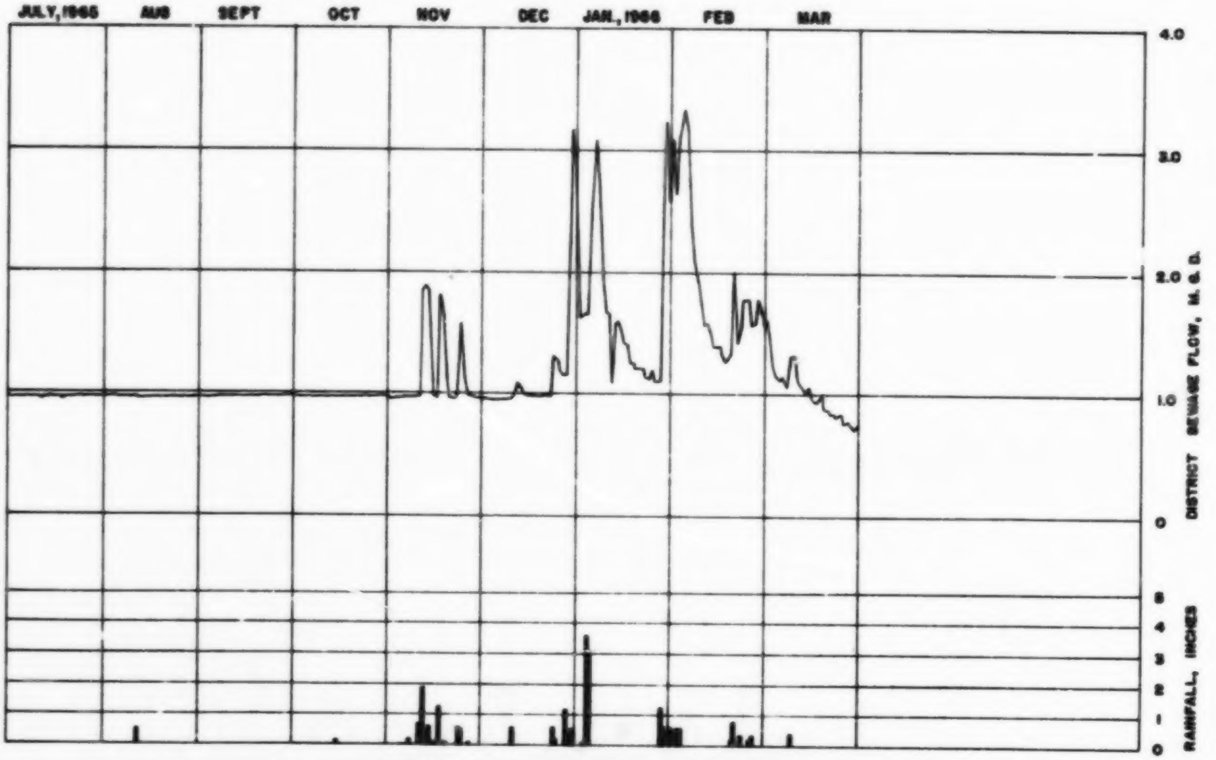
RAINFALL & DISTRICT SEWAGE FLOW

JULY, 1963 THRU JUNE, 1964



RAINFALL & DISTRICT SEWAGE FLOW

JULY, 1964 THRU JUNE, 1965



RAINFALL & DISTRICT SEWAGE FLOW

JULY, 1965 THRU MARCH, 1966

SUMMARY AND CONCLUSIONS

SUMMARY OF COLLATION

The initial objective of the demonstration project was the collation and analysis of the backlog data pertinent to line sealing. This collation has been accomplished, and an appendix volume to the project report contains the collated data.

The assembling and analyzing of the material for collation underscored the magnitude and importance of the infiltration problem in the Sonoma Valley County Sanitation District. That the use of the asphaltic method of line sealing was increasingly successful can be shown by comparing the 1954-55 winter's experience, including 15 days of treatment plant bypassing treatment, with the 1965-66 winter in which plant bypassing was limited to 8 days. Precipitation during these two winters totalled 18.16 inches and 22.22 inches, respectively.

Review of the exploratory and experimental field work conducted between 1954 and 1965 shows that while the asphaltic method of line sealing seems to be a satisfactory corrective measure, the need exists for a more sophisticated method of determining sewage flows in order to evaluate the degree of sealing success achieved. Flow measurement through the use of existing flumes and nozzles lacks the sensitivity required for accurate measurement, and these devices are not sufficiently portable to allow extensive usage in wide-spread areas. Correlation between rainfall rates and sewage flows would also be more realistic with improved flow measurement.

Inclusion of the field book material and the field diary notes provides an historical basis to which future developmental work can be referred. The recording of problems encountered in all aspects of the conception and development of asphaltic line sealing, together with successful and unsuccessful attempts to arrive at solutions, provide a wealth of data which can be used to minimize unnecessary duplication of research and development effort.

Collation of the colored stereo slides showed that the comparison of wet and dry weather flows in District manholes provides visible evidence of line sealing success; and is a graphic history of the line sealing process.

SUMMARY OF FIELD APPLICATION

Also considered a primary objective of the project was the investigation of the line sealing under a variety of field conditions. The results of this investigation are summarized herewith.

Application generally was conducted using normal procedures developed for line sealing. The technique of "burying" the horizontal applicator piping was further developed in this demonstration project. Prior to the demonstration project, the horizontal applicator piping was usually installed by fastening to the road surface. Experimental use of the channeling technique has proved its practicability. While road patching is required, the continuous re-nailing of strap fasteners is avoided and less day-to-day maintenance is needed.

In the Bodega Bay Test, the use of salt water intrusion to accelerate breaking of the RS-1 pointed out the positive results obtainable from this approach. Salt water in the form of tidal water tends to facilitate sealing by reducing the time required for hardening the asphalt envelope. However, care must be exercised in order to preclude the possibility of breaking too early and thus defeating the purposes.

As a result of the Sonoma Valley Test, the need for early determination of subterranean drainage areas and the early blocking of these areas is evident.

In those areas where subterranean voids are common, the approach should be to apply the "salting" technique as early as possible. By breaking the RS-1, a dam or "floor" can be built up through alternating the application of the asphalt and the salt water. Placing a floor under the sewer line reduces the excessive use of sealants to a reasonable level.

In determining the optimum spacing of applicators, field tests indicated that no "standard" spacing can be specified. In soil types such as dense clays or "adobe", spacing of less than fifteen foot centers is required. Field experience and field excavation proved the flow of the sealants to be slow and restricted through dense soils. Similarly, in very loose material, closer application would also be required because of the tendency for the material to flow in a vertical rather than a horizontal pattern. In this case, however, the length of application time would be shorter since the asphaltic sealant moves faster in a loose material.

EVALUATION OF RESULTS

It is recognized that evaluation of sealing results by comparison of "before and after" exfiltration does not constitute a precise evaluation method. The introduction of extraneous conditions such as ground water buildup in trenches and variable head in exfiltration testing place this form of testing in the category of only determining trends rather than determining actual quantities or percentages of reduction in line leakage. Thus, to state percentages based on average test rates of exfiltration, as shown in the "Study Area" portion of the report is not to be regarded as a statement of a fixed, definite result.

A comparison between exfiltration and infiltration rates can be made on the basis of the Bodega Bay tests. Under the exfiltration test conditions, the maximum rate of water flow out of the joints was approximately 15 gallons per minute prior to sealing. Infiltration under a rising tide amounted to a maximum of approximately 0.5 gallons per minute prior to sealing. Subsequent tests, after sealing, showed results of approximately 0.1 gallon per minute for exfiltration and 0.0 gallons per minute for infiltration.

Experience has shown that the process "improves with age". Excavation of lines treated with only SC-1 in the early days of "cut and try" approaches - five years and more ago - show the primary sealant to be quite adequate. In fact, the discovery of the presence of an asphaltic concrete type of material in these older trenches is not uncommon.

The variety of field conditions utilized in the project indicate the universal application of the process. No attempt was made, however, to seal lines during periods of near-freezing temperatures. In the normal sealing operation in the Sonoma Valley County Sanitation Districts, asphalt application is discontinued during winter months; and other activities such as drilling and applicator placing are pursued.

Results of post-sealing excavations show the tendency of the sealant to follow very closely the travel of water or exfiltrated sewage along the longitudinal axis of the trench. Frequently, the water course will be below the pipe invert. However, in most cases when a joint is reached the sealant tends to travel circumferentially around the joint, thereby sealing it regardless of the path between joints. (See Plates #88 to 95)

An economic evaluation was not attempted as part of this project. Because the test areas were widely separated and because the lengths of line involved in the study areas were not of the usual length used in normal sealing operations, an evaluation of costs would not be representative of actual field costs. Sealing cost per foot of line have been previously determined and generally average 25 per cent of the cost of line replacement.

Visual inspection of the plants, flowers, trees and grasses adjacent to streets, rights-of-way, and easements in which sealing had been completed showed no effects of the asphaltic application. Asphalt-like streaks on one oak tree (See Plate #96) were the only possible "evidence" of any travel of the sealant into vegetation, and this case is open to question.

ADVANTAGES OF ASPHALT SEALING

Basic among the advantages of this method of line sealing is that of non-interruption of sewer use. Because the application is external, the sealing is performed on live lines. Except for testing and salting, the lines are not plugged during application of the sealant.

Capitalization costs are not excessive in view of the continued use of the sealing equipment. Most of the equipment is of rugged construction and can be temporarily rented; or, if purchased, is readily available. Similarly, the materials used are in common use and present no problems as far as availability is concerned.

The field crews performing the sealing operation require no special training or advanced mechanical skills. Because of the simplicity of operation, minimal control is required; and much of the operation is on an unattended basis.

Asphaltic line sealing is well suited to areas in which seismic disturbances or earth movement must be considered. By its nature, the material remains in a somewhat plastic state indefinitely and is not affected by movement of the pipe joints.